NATURE STUDY

NATURE-STUDY LESSONS

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INTRODUCTORY.

NATURE-STUDY METHOD.

All the world is newer and stranger to the young child than America was to Christopher Columbus when he first set foot upon it.

The child acquires knowledge by what he is told and later by what he reads, but the first knowledge, and, indeed, most of the knowledge he receives in his earliest years, is, and must be, acquired by the use of his own powers.

A truth discovered by the child's own effort or experience is as useful as if learned by hearsay; but in many cases the mental power and disposition developed through the efforts put forth by the child in search of a truth are more useful to him than the truth itself. Hence, usually the child who acquires useful knowledge by means of his self-activity is more than twice blessed as compared with the one who gets the same knowledge second-hand.

NATURE'S METHOD OF TEACHING.—Think how much a child learns by this natural method before he is old enough to go to school. In the school-room, the very place devoted to learning, should wise Nature's favorite method of teaching be neglected or forgotten? This misfortune has happened when the child has formed the habit of depending almost entirely on the teacher or on the book to tell him what he does not know. He is not unlike a jug set before a fountain to be filled. He feels that his memory bears the chief responsibility for his education; he loses the disposition, if not the power, to find out things by his own efforts.

CRAMMING NOT EDUCATION.—Observe an intelligent farmer feeding his stock. How differently he treats the animal which he wishes to fatten from the one he wishes to make strong. The former is kept quiet and is plentifully supplied with luscious grass or chopped food, but the latter is given exercise and training as well as a different kind of food. A child may sit at his desk and

absorb a great mass of knowledge from teacher and book. By the more natural way of learning—the investigating method—he may not seem to know so much, but his mind will be stronger.

When we come to solve the numerous problems of real life, we shall not have a teacher to depend upon, nor will there be any book into which we may look for direction on every occasion. We have to rely on our own powers; hence, we should be trained to use them.

Exercising our faculties under wise guidance not only develops them, but shows us their capabilities and their limitations. Taught by the Nature-study method we become self-reliant, while our confidence is tempered by a wholesome cautiousness.

THE SENSES THE GATEWAYS OF KNOWLEDGE.—The first knowledge comes to the little child through its senses—the sense of sight, the sense of hearing, and the other senses. These are sometimes called the gateways of knowledge. At first their service is very feeble, but with practice they become stronger. They are so useful that no pains should be spared to make every one of them efficient and to train them all to the highest degree of efficiency of which they are capable. Some eminent authorities teach that, if the training of any sense be neglected until the age of twenty, it will be difficult or impossible to improve it much after that age.

Sense-training is not only constantly useful, but also adds greatly to the enjoyment of life. Much of the best literature can be fully appreciated and enjoyed only by those who can vividly image the ideas suggested.

Sense-training is one of the aims of Nature-study. The Nature-study teacher devises a graded series of exercises to train the senses to acuteness and the mind to discriminate between closely-allied sensations, and to image at will the form, color, odor, sound, taste, weight or "feel" of objects. Examples of a few of these exercises will be found in the Lessons on the Senses.

OBSERVING SHOULD BE FOLLOWED UP BY REASONING.—While the Nature-study method is careful to train the senses, it is no less solicitous that the proper use be made of what the senses bring to the mind. Observing includes more than merely attending to the sensations; the most important part of this exercise is

the comparing, relating, judging and expressing of thoughts. Teaching to observe includes training the mind how to make the best use of what the senses bring to it.

The expression of the steps of an investigation is not confined to speech or writing. In the best nature-study lessons all practicable means of expression are employed—drawing, modelling, making and gesture, as well as oral and written statements. So there is physical as well as mental training. A good nature-study lesson may be based on the replacing of a broken window-pane or the repairing of a door-lock, the digging of a drain or the cooking of a meal. The neighboring farm or the garden attached to a school, fortunate enough to have one, will be most fruitful of excellent subjects for nature-lessons in great variety.

METHOD AS IMPORTANT AS MATTER.—From what is stated, one can easily see that Nature-study is rather a method than a subject, and, although it deals largely with plants, insects, birds, and changes produced in the air and on the surface of the earth by natural forces, yet it does not exclude anything which the child can observe and reason about. Its spirit may be applied to a greater or less extent to the other subjects of the school programme, especially to geography and to physiology. To the arithmetic class, the teacher may, for example, give the problem: "In a pile of wood 16ft. long 4ft. wide and 6ft. high how many cords?" Something of the nature-study quality is given to the problem when the teacher says: "There is a pile of wood in the yard, take your rulers, measure it, and calculate how many cords there are in it."

In the real nature-study exercise the teacher is more anxious about the way the pupils observe, and the way they reason about what they observe, than about the information obtained. But life is too short to learn all that needs to be known by the discovery method. The wise teacher judiciously combines information with investigation. In many lessons a question will arise, the answer to which the pupils have not the means of discovering or which would take too much time to discover. Here the lesson may stop; but often the necessary information may be supplied and then the investigation be resumed.

Where so much that seems of nearly equal value for training is at hand, the teacher will choose the lines of investigation that promise the largest returns in the usefulness of the knowledge acquired.

USE AND ABUSE OF PICTURES.—It is very important to distinguish between a nature-study lesson and an information lesson about an object in nature. It is better that the learner should be directed in the way to find out the fact sought than that he should be told it. The child who says to his teacher or fellow pupil, "Please don't tell me yet, I wish to try to find out for myself," has likely acquired the right spirit. Another evidence of the right mental attitude is given when the learner prefers to examine the real object rather than a picture of it. The picture is an expression of some other person's study of the object. Usually it is like the answer to the problem in arithmetic, it should not be seen until the investigation is concluded. In the nature-study lesson, a picture may be of use to a child who needs assistance in the art of expressing a conception obtained by his own researches. But in the mere information lesson the child seeks to be told the facts and is indifferent whether he obtains them from teacher, book or picture. The pictures and diagrams in this book are intended to assist in defining technical terms or suggesting points in the method of expression, but all pictures have been excluded that might stand between the child and the object of his investigation.

NATURE-STUDY, MORAL AND ESTHETIC.—Nature-study lessons properly conducted, not only train the observing and reasoning powers, but also increase capacity and desire for enjoyment and enrich and ennoble the sympathies. Observation of the bird, the insect, and the reptile, can hardly fail to make the observer more careful of, and sympathetic with, that wonderful life and form which God has given his creatures, so easily destroyed, but impossible to restore.

The charming grace of character called humility is surely cultivated by the study of nature. The more one learns, not alone of stars and mountains and trees, but even of the apparently insignificant things like the pebble, the grass, and the worm, the more he realizes how limited man's knowledge is.

"Let knowledge grow from more to more,
But more of reverence in us dwell;
That mind and soul, according well
May make one music as before."

HOW THIS TEXT-BOOK IS TO BE USED.—The lessons in this book are not exhaustive either of the subjects, suitable for investigation, or of the treatment of those taken up. The order of the lessons as well as the order of the parts of each one may be varied to suit circumstances. The class may begin at any lesson in the book or even at the middle of a lesson. The important feature of expression is left almost wholly to the discretion of the teacher. The same subject may be investigated by all the classes from the primary to the highest, but the expression of observations and judgments must vary with the age, attainments and circumstances of the pupils. The youngest tot in the kindergarten may learn something by observation of the insect or the star, for example, but the wisest people in the world have not yet learned all about them.

"Flower in the crannied wall,
I pluck you out of the crannies;
I hold you here, root and all, in my hand,
Little flower—but *if* I could understand
What you are, root and all, and all in all,
I should know what God and man is."

NATURE-STUDY BOOKS.—It is strongly recommended that pupils, able to write and draw, should make neat, and, if possible, artistic records of their studies, in books kept for the purpose. In addition to the records of investigations and illustrative objects that may be conveniently attached to the pages, each subject may conclude with a composition or essay setting forth in a connected manner the history and results of the investigation. Language training may be made a valuable incident of the nature-study lesson. For English composition and drawing lessons many of the nature-studies offer incomparable subjects.

APPARATUS.—Sharp eyes and willing hands are the most necessary instruments in the nature-study lessons. A great many things might be named in making up a complete outfit for a school, but the more important of these would be one or more good magnifying

lenses, a compound microscope, an opera-glass to observe distant objects, such as birds and stars, a manual-training bench with its equipment of tools, and a well-appointed school garden.

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INTRODUCTION.

By Edward F. Bigelow, A. M., Ph.D.

Author of "How Nature Study Should Be Taught."

There are as many definitions of nature study as there are true naturalists, and as many methods of teaching it as there are true teachers. All nature study teachers are divided into groups, according to the text book which they have studied, the normal school they attended, or the schedule and instructions supplied by the school superintendent. The individual method is always successful; others are usually only partly so. The essential point is to encourage a love for nature that will lead to a knowledge of it. That love and the knowledge which is its outcome, will both be available in making life worth living.

Hence it is that a truly successful book of nature study, must be either one of general principles as a help toward the inspiration of the pupil, or one of material. The successful book of methods in nature must always be unwritten in the heart and head of the teacher. It is a thing to be felt, to be lived, to be evolved from one's own individual method, rather than to be put into formal didactical rules.

The best of all such books can act only as a suggestion to the teacher. I am one of those who believe that no

person can teach nature study unless he himself is in love with nature; unless he feels a cordial interest and a true sympathy with what he is trying to teach. A watchmaker cannot teach blacksmithing, nor a blacksmith teach watchmaking. The delicate touch of the artist fails when he clutches the hammer and the tongs, and the muscular strength of the smith is wasted when he tries to adjust a hair-spring, or to pierce a ruby to receive the pinion of the balance wheel. The watchmaker feels something like scorn for the swashbuckling swings and blows of the smith, much as he may appreciate the results, and the blacksmith smiles behind his great hand at the delicate touches of the pale man who adjusts his watch, much as he, too, may appreciate the result, for each feels that what he can do is the only thing worth doing. The feeling is a natural one to the natural man, but in the educated teacher of our schools and academies, such a feeling is perhaps open to criticism, as an evidence of narrow-mindedness and of a greatly restricted horizon. Yet such feelings do exist among teachers who, I am free to say, should be above them and should assuredly know better. The mathematician thinks that there is no study so valuable as mathematics for expanding the mental faculties. The chemist thinks and says, too, that his science is, if not the most useful to mankind in general, at least—"Well you are not a chemist, so you may not appreciate what chemistry has done and is doing for the world, and I can not now stop to teach you what I know; but I should advise you to take up the study."

I suppose that every person, with even a restricted leisure, has a hobby, and nothing can be more praiseworthy and helpful than a hobby, provided you do not ride it

too often. Unless you are the chemist to some public institution or to some municipality, it may be as well to leave the retorts at home when you call on your lady friends; and the man who lives in an atmosphere of mathematics would do as well to take a brisk walk and read a chapter in "Uncle Remus," or in "The Adventures of Baron Munchausen," before he goes into any society except the "Society for the Investigation of the Higher Mathematics." Such persons, who are so wrapped up in their specialties, and so enraptured with them, may be, I admit, a perfect pest to the rest of us, who perhaps have other hobbies, which we should like to ride for a few moments to show how well we can do it. But they are a nuisance only when they are outside of their special and particular habitat. When there and when doing the work pertaining to the position, they are gods among other men, who can lead to a crown of glorious knowledge and to a happiness blazing with the bliss of learned appreciation of the world's wonders, and of the goodness of an Omniscient God. The school teacher who loves nature, can teach it. If she does not she cannot. If she is not a lover of nature, and still tries to teach nature study to a child, she is something more than a perfect pest, for she is a living lie. An ardent chemist or the mentally active mathematician may each become a nuisance; a teacher of nature study not in love with nature is a dangerous pretender, who should retire to another department which she may really like, and in which she may be able to do good work.

"Teacher, say teacher, what is this?" The child's hands are soiled, finger nails black-bordered and untrimmed, face sunburned and smeared with the remnants of a sandwich lunch; and a dried leaf clings to the sticky,

fingers, with a slug slowly crawling across the surface. "Say, Oh say, teacher, what is this?"

"You dirty child! That nasty slug; throw it away. It is nothing but a slimy snail. Throw it away, I tell you, and go wash your hands; yes, and your face, too. A nasty slug! The idea! And call me Miss Jones, the next time you address me, and not 'teacher'."

The most celebrated naturalist in America, a man whose fame was world-wide, a man who could take a single fossil bone and from it build up an entire animal, that learned man stood with a boy in a sunny field one day under the blue sky, and with the soft breezes of spring stirring his gray hair and tossing the boy's curls. The man was Joseph Leidy, and the boy,—but that is of no importance. The boy held a leaf in his hand, and a slug was slowly crawling across the surface. In silence he held it toward the man, who stooped until his time-stained locks mingled with the boy's untouched ringlets, and he said, "Oh, the pretty creature! Some persons dislike snails except when they eat them in France, but to me they are graceful animals. This kind is well named 'slug', because it is really sluggish and slow in its movements, but there is a world of information to be had from even so lowly a creature as a snail. See, there on the back is a little low hump covering all the shell that it has. But if we look about on the bushes and the willows, we shall find some with complete shells to protect the whole body. Turn him over, Jimmie, for a moment." And with a blade of grass that great and learned man, pointed. "Now watch," he said. "Did you see him open his breathing pore? Look, Jimmie, and you can see him take a long breath. Did you notice the little black aperture appear and close again? It is

the opening to the lung. In the shell-bearing snails it is just under the edge of the shell, and usually invisible unless you look for it. They all need air as surely as you and I."

Dr. Leidy could teach nature study, and the reason is obvious. The alleged "teacher" who called the slug "a nasty thing; throw it away," could not, and the reason is likewise obvious.

In the "Concluding Remarks" to his magnificent monograph on "The Fresh-Water Rhizopods of North America," this same Dr. Leidy says:

"The objects of my work have appeared to me so beautiful, . . . and so interesting as indicated in their history, which forms the accompanying text, that I am led to hope the work may prove to be an incentive, especially to my young countrymen, to enter into similar pursuits. The study of natural history in the leisure of my life, since I was fourteen years of age, has been to me a constant source of happiness, and my experience of it is such that, independently of its higher merits, I warmly recommend it as a pastime which, I believe, no other can excel. At the same time, in observing the modes of life of those around me, it has been a matter of unceasing regret that so few, so very few people give attention to intellectual pursuits of any kind. In the incessant and necessary struggle for bread, we repeatedly hear the expression that 'man shall not live by bread alone,' and yet it remains unappreciated by the mass of even so-called enlightened humanity. In common with all other animals, the engrossing care of man is food for the stomach, while intellectual food too often remains unknown, is disregarded or rejected.

"'Going fishing?' How often has the question been asked by acquaintances, as they have met me, with rod and basket, on an excursion after materials for microscopic study. 'Yes!' has been the invariable answer, for it saved much detention and explanation, and now, behold, I offer them the results of that fishing. No fish for the stomach, but, as the old French microscopist, Joblot, observed, 'some of the most remarkable fishes that have ever been seen,' and food fishes for the intellect.

"To my pupils, both of the University of Pennsylvania and Swarthmore College, but especially the boys and girls of the latter, who have attended my lectures on natural history, the work will be of interest, as they will recognize in its illustrations many of the simplest forms of animal life with which they have been made familiar through my instruction. Indeed, in the course of preparation of the book I have always had my pupils in mind, and I shall be glad if it serve as an additional aid to their studies."

None but a lover of nature could have written that magnificent monograph. None but a lover of nature would have had his pupils in mind as he wrote it. None but a lover of nature can teach nature study. I have said that more than once; I am willing to repeat it in every paragraph that I write on this subject of nature study. If you do not yourself love natural objects, never be misled into the attempt to take charge of a class of young persons in nature study. An exceedingly small amount of experience in such conditions will speedily "prove it to you," as Uncle Remus says, that you are "forepreordinestinated" to fail.

As well might you attempt to write a book "How to Win the Love of your Pupils," or "How to make Other Persons Gracious, Kind and Courteous." Love them, be really gracious, kind and courteous at heart, and the transferring of these sentiments to your pupils will be accomplished readily and as surely, as rays of light will emanate from a luminous body.

The authors of "Nature Study Lessons" have not laid down a schedule of nature study methods and topics for each week in the school year. They have merely provided details of material from a few natural objects of wide range. They have wisely left it to the true teacher to utilize this material in her own way.

The merits of the book in supplying detailed suggestions for sharp seeing are self-evident to any nature-loving teacher. She needs no introduction to tell her that this is good material, for she will at once recognize what is helpful in her work. Neither does she need to be told how to use it, for she will make her own method, and use best in her own way such of these observations as come within the scope of her own interests. No other

will be helpful to her. The material is good to those who make it good, and good only as they make it good.

To the child interested in butterflies there is no use in persistently insisting on an interest in snakes, though you are ever so ardent a herpetologist. And the same thing is equally true in the converse, if the child takes an interest in snakes and you in butterflies. The value is not so much in the material as in the method.

Here are chapters on four-footed animals, on birds, insects, trees, plants; on geology, physics, meteorology; in fact, something is selected from almost every class of natural objects. Take your choice of as many things as in your own method will win the child to the love of nature that you are supposed to possess. One fact that awakens is worth more than a thousand that are a burden.

Real Value of Nature Study.

As the flicker flies through the groves in the dead of winter, shouting "wake up," "wake up," "wake up" into spring, so nature study says to the child mind beset with tedious tasks and irksome discipline, wake into the life of your own activity. Winter is acted upon and repressed by the intense cold. Spring wakes up in newness, it leaps out bouyantly from internal life. It takes all seasons to make a year, but there should be a little of spring in all these seasons.

Mathematics say, *train, train, train,* for future business dealings, for sharp reasoning, for skilful logic with your fellows, and to be able to count your money, and your acquaintances.

Grammar, reading, writing, spelling, say *prepare, prepare, prepare* for interchange of thought with your fel-

lows. All these are generals, captains; you are one of the army in the battle of life. They are disciplining the child to become a part of the great socialistic machine.

Nature study comes in and says step out of the ranks in the majesty of your own personality. You are, it is true, a part of that machine, but not chiefly so nor always. You are yourself. Think and act for yourself. Bow down no longer under disciplinary, irksome tasks, but wake up, in your own personality. Mathematics and literary studies are cosmopolitan, nature study is individual life. Where personality is not valued leave out your nature study.

Remember always that "Man shall not live by bread alone, but by every word that proceedeth out of the mouth of God." Since God created nature, and in every human heart placed more or less affection for her, since he has created all natural objects by the word of His mouth, it is one of the mysteries that He allows so many human beings to pass through the world with their eyes riveted to the ground, as if they were holding communion with the offal of life or with their own dusty shoes. You recollect the old story of the man who once picked up a shilling in the road, and never again saw a tree, nor a flower, nor the clouds in the azure sky, nor heard a bird sing, nor the voices of the children at play in the streets, nor even the tinkle of the hurdy-gurdy; but he found a goodly number of shillings before he died, and when he died all that he knew was a shilling, and he had two of them put on his eye-lids to keep them closed, for even in his death he thought of shillings. That man had an ancient ancestry, and he left an ever lengthening line of descendants.

I think that it matters but a little in what way the child's interest in nature is awakened, provided only that it is really stirred by a teacher who, like the illustrious Professor Joseph Leidy, thinks of his pupils as he writes a book so simple, so complete that it is a recondite treatise. Yet you would perhaps be amazed if I should call that book by that term. "What! Recondite? That book? Why, I read that book with the greatest interest and satisfaction." Of course you did. And have you failed to discover the reason? Leidy himself tells you, for he says, "The study of natural history in the leisure of my life . . . . has been to me a constant source of happiness, and my experience of it is such that, independently of its higher merits, I warmly recommend it as a pastime, which, I believe, no other can excel. . . . In the course of preparation of the book I have always had my pupils in mind."

There your finger touches the very spring of its excellence. "I have always had my pupils in mind." A learned man among learned men, he always had his pupils in mind, and wrote one of the most inspiring and elevating and helpful scientific books in the English language. It has always seemed to me that these exceedingly learned persons who write books on natural history in a language that died a thousand years ago, are exceedingly selfish persons, although they may be as much wiser than I, as the sun is brighter than a poor little lamp. But I should prefer to have my pupils in mind, and write the "Fresh Water Rhizopods of North America," than to indite the Latin Salutatory at your next commencement. Yes, but every scientific man understands Latin. Perhaps he does. If Dr. Leidy had written that monograph in Latin, it might have pleased his

vanity and excited the envy of other scientific men, but it would never have aroused the wide-spread interest in the Rhizopods that it did arouse. But bless the man, he had his pupils in mind and he wrote one of the most satisfactory, the simplest, and one of the best scientific books that has ever been composed in the English language. I found my first Rhizopod many years ago. It was a beautiful thing, with a delicate something around it. I could not decide what, but it was so daintily sculptured in microscopical hexagons, so charmingly tinted, that I felt that it must be the rarest gem from one of nature's rarest mines, although I had taken it from a meadow ditch. I am willing that you should laugh at my ignorance, but that Rhizopod was so beautiful, that I tried to cultivate it so as to have a supply, and to discover, if possible, what it could be, for I could not guess. As I had captured it in a ditch, I attempted to cultivate it in water, and I waited and watched, and got up in the night to see what it was doing, but at the end of my patient waiting, it remained what I have since learned it all the time was, only a dead and empty shell, but beautiful, dainty and graceful, a common *Arcella,* such as abound by the hundred in the nearest ditch. It was not until I had read Dr. Leidy's entrancing monograph on the Rhizopods long after I had abandoned my investigations, that I learned what I had. Do you suppose that I now fail to recognize a Rhizopod when one comes in the field of my microscope? As a teacher and lecturer I try to have my pupils in mind, for I recollect how I groped, and faltered, and how blind I was, with not a human being to help nor to encourage, but many to say, "What nonsense! It is no good. Let me look! Pshaw! It looks exactly like the kitchen oil-

cloth. That thing? Is that a living animal? It may be, and I don't care; it looks like a whale. I am going to the theatre."

I care little how the interest is aroused. All that I want is that it shall be aroused in some way, either by the nature-loving teacher, or by the instinctively nature-loving child himself. Sometimes a practical experience may be beneficial. A little girl whom I know is ever on the alert to enlarge her experiences in the natural world that surrounds her. Recently she saw a big fly in the grass. She had never met its like, as it was banded with yellow and black. To investigate it, she picked it up, and then she wished that she had not. But she felt better, and knew more, after the pain had subsided, and hereafter hornets and Mabel will be on good, if not intimate terms. "What made him do that? I didn't want to hurt him, why should he hurt me so? What was it he stuck into my finger? Do you know what it was, and how he made it hurt so bad?" The teacher was overwhelmed with questions in the anatomy and the physiology of the hornet, and the little girl had not only her finger, but her active mind full of hornets. I am not suggesting that you should take your class in nature study to the nearest hornet's nest, and to stir it up to teach them the physiological action of formic acid, but that a bit of practical, if at times painful experience, will do no permanent harm, and may do as much good to others as it has done to the little girl, for she is alive to any nature study interest that comes to the surface, although she is now cautious in making acquaintance with previously unknown creatures. I carry within my own mind, within its most retired and private recesses, a vivid recollection of my first interview with a strong and lusty

nettle. Perhaps you think that I now fail to recognize a nettle across the road, with all its relatives, stinging and harmless? If you do you are wrong. I stop and look at them always, and we bow cordially as I pass by, and one of the most treasured preparations in my microscopical cabinet, is a slide of the stinging hairs of the nettle. I do not much care how you arouse the child's interest in botany; sting him with a nettle if you will, but I do want his botanical interest aroused. If you know anything about hornets, you can talk simply about them, and then take your pupils on a hunt for a hornet's nest, and while you stand at a safe distance, you can expatiate on formic acid, if you will, but you will have it in your power to kindle an undying incitement to pleasant thought and reading.

Regard for the Individual.

One great mistake often made in all congregations of old or young, is to overlook the value of the individual. The school expects all to come to its gradation; deals in classes and grades. But not so our great teachers. Socrates taught not in classes, but drew out from the individual. This process did not promote large classes but it made a Plato, and through him by the same method an Aristotle.

This is ever the method of the true educator. The Great Teacher who drew his inspiration and examples from the wilderness, the mountain peaks, the rivers, the fields, the birds, said not, "We will get a great body of people together and conquer the world spiritually by the wholesale." No, He dealt, with the individual,—a very few of them principally. He laid more stress on private prayer than on public worship.

I once knew a boy who went one evening with his mother to call on the minister. Shy and awkward, he sat in the corner and had every kind of a thought except a religious one, and wished himself at the bottom of the sea rather than where he was. Presently he became conscious, in a lull in the conversation, of a beckoning finger, and of a kind voice that said, "Come over here; I want to show you something." The boy, in all his twelve years of life, had never even heard of a microscope. A pocket-lens was an unknown quantity. To him the ability in a bit of curved glass to "make things big" was what Emerson once said of God, "the x in the problem." It was no more, for he had never even heard of it. The minister lit the lamp, and with a bit of lichen-covered bark in one hand, and a pocket-lens in the other he said, "What do you think of that?" The thoughts are not recorded, but the light blazed from mountain peaks, and fainted in soft shadows as transparent as nature alone can make shadows, and which the artist tries in vain to imitate; dark caverns seemed to burrow into gloomy depths; diamonds sparkled on the heights, and dimly gleamed in the depths of gray valleys; green particles seemed a velvety lawn across which suddenly sauntered, from a shadowy glen, a mighty beast, unknown even in the boy's dreams, a beast with many legs, with terrible horns that waved and threatened. It was stupendous, yet it was nothing but a double convex lens, a dry lichen, a good man, an ignorant boy, the lamplight and a plant louse. But it waked up the boy, and to-day he stands an equal among botanists who have investigated and written; he bends his back and strains his eyes every night of his life over his microscope, with which he has made discoveries, and with whose help he has written

books that stand the test of faithful use. You can never tell where the ripples will reach, when you toss a pebble into the water. The minister is dead long ago; but the boy's books and papers are reaching, like the ripples, into the unknown distance.

And do we not in the affairs of the nation, make patriots shout too much about ourselves? We are a great nation, we raise so many crops, we have so many manufactures, we are worth so much money, we have such large battle ships, we have such impregnable forts, guns of such huge calibre, and valiant men behind the guns. We are a great nation, and while we welcome to our shores the sons and daughters of all lands, yet on all occasions where the stars and stripes are floating in the breeze, we insist with much gesticulating oratory, that you must not forget, that if your fathers and mothers, your brothers and sisters, back there in the fatherland all so dear to you, do not treat us just about right, we can and we will make their blood run in little brooks along the dry ground. We are the people. We are a mighty, commercial, fighting people, and when we say "thus" and "so" then "thus" and "so" it must be. In this way do we make patriots,—lovers of country? No, not all. Down deep in the heart of each one there is a feeling, strong and sure, that patriotism is a matter of the individual, not of the masses. In spite of Fourth of July, with orations accompanied by explosions and by blasts of fire; in spite of the fact that the records of our country's doings (even those records used in the schools under the name of American History), devote more space to war than peace; down deep in your heart and in mine is a feeling that this is not the true patriotism. For by and by there comes some sensible peace-loving patriot, so

attuned to real love of country that he ignores all these pyrotechnics of patriotism, all these absurdities of substituting the watch dog, and the policeman, for the true home, and says no fight, no blood, no "we".

"From every mountain-side
Let freedom ring.

My native country, thee,
Land of the noble free,—
Thy name I love;
I love thy rocks and rills,
Thy woods and templed hills;
My heart with rapture thrills
Like that above.

Let music swell the breeze,
And ring from all the trees,
Sweet freedom's song;
Let mortal tongues awake,
Let all that breathe partake,
Let the rocks their silence break,—
The sound prolong."

True patriotism is love of country by the individual, with all the fight eliminated.

Civil History and Natural History.

This fighting patriotism is given too much prominence, not only on all public occasions, but in the public schools. It is well, of course, for our young folks to be taught about our national struggle for existence. It is well for the young folks to know that the city in which they live takes proper measures for the protection of their home. But of the family home no one would think of laying all, or even the greater part of the stress, upon these pro-

tective methods. Yet strange to say, such stress is laid upon our loyalty to our national home. One has only to run over the pages of the average school history to see the prominence given in description and illustration to wars, to great generals, and to monuments that commemorate battle fields. All these things, essential as they are, are but the outcome of the real patriotism, *methods of protecting* the country to be loved.

In so far as civil history has to do with the individual, it is too much a matter of dominance over others, of stern ambition and of leadership. Civil history takes part in the pernicious sentiment taught in too many schools and in the life outside of the schools, and which may be expressed in the common saying, "There's room at the top." This common saying that so often passes as the expression of a truth, is nearer a fallacy. There is no room at the top. In matters financial, there is no room at the top. We cannot all wear a silk hat, carry a gold-headed cane, have a big bank account, play golf and ride in the latest style of automobile. Those things must always be limited to the few. It is a lie to say that there is room at the top. The top itself is now already overcrowded. Just at the present time true educators everywhere are working and crying out against the pernicious, yes, even dangerous tendency to laud the aristocracy of wealth, and to decry the dignity of labor. Many a child in our schools is studying with the one idea that he can get to the top; that he may be some great person; may escape from manual labor, and get a living by his wits. Civil history as frequently taught adds fuel to the flame. It says, "Here was a great general, a great president that began life in a humble way and of lowly parentage, who has now come to some great thing." Civil history for-

gets that those humble parents (*aside* from the production of a prominent son) had just as important a mission in this world, and could get just as much happiness out of that humble mission, as can the talented son. The world needs not more at the top, but more conscientious, educated, contented people in the "lower positions," falsely so called. Natural history is the antidote to pernicious civil history. It says, laud your scarlet tanagers all you please, but I say that earthworms are more important. There is room for a few scarlet tanagers at the top of the trees, but there is more room for farmyard hens to scratch at the roots.

Literature proclaims the great and talented writer. It has praise for the great novelist and the great poet. It has no word of praise for the reporter on the village paper who faithfully records a local occurence, who takes matters not on hearsay, but investigates the details and records them correctly.

But natural history never tries to make an eagle out of a crow by any amount of sunstaring. It never tries to do any so called raising to the top of a good shoemaker by making him a third-rate minister. But it does ever strive to inculcate the lesson that we should love all natural things; that everything can be happy, and can adapt itself to its environment and capacity. The study of nature is an important factor in bringing about the day when society shall open its door to the honest and well-educated artisan of whatever name; when praise shall be given for good work wherever it may be, whether in the ground, the waters, or the treetops. From our civil histories we may learn of those who excel and struggle, but from our natural histories, of those who live faithfully in that position in life to which they shall be

called. It may not be given to you or to me to lay hold upon great things, or to subdue to our will any great external force, but it is given to you and to me to make the most of our present opportunities.

A World of Discovery.

We all like to discover and to tell of some new thing. Natural history is preëminently the field in which we can exercise this faculty. What can a child discover in mathematics, or in literary studies? It is chiefly his duty to follow in the steps of others, to do the task that is assigned. But in nature study his spirit is free. He may be an original explorer; he may perhaps see something that no one else has ever seen. And, then the boundless pleasure of such scenes and the telling. His spirit breaks forth exultingly as out of a prison house. He is the individual in full exercise of his powers. The child recognizes, and rejoices in the recognition, that his ability to discover depends not on years nor on long training, but upon his own sharp eyes, and a loving, active mind back of them. He joyously bounds over time, and years of study, and stands an equal with his teacher, the only phase of school work in which teacher and pupil can be real companions. How affectionately close they come; this is the real *comaraderie;* it wins the right kind of friendship. It develops both teacher and pupil.

And as the child and teacher never really know the field and forest till they have entered therein, so the teacher never knows the child till she has entered into this real companionship. In the presence of Mother Nature we are all children, loving her and loving each other. As we all must go into nature's domain to make

discoveries of her ways, so must the teacher go into the heart of the child if she would really know the possibilities that are there. The best, and the worst, too, must be discovered. There may be latent forces deep in that child, which it is your duty as a teacher to discover and to develop. You will never reach them through five times one are five, nor the noun following the preposition is in the objective case. Leave your desk, and with the child as a true companion, pass through the door of nature, there to study and wander in beautiful paths, both of you being children in the kindergarten of God.

Character Building.

It has been said of music that it is the only art that cannot bring degrading thoughts to the mind. Sculpture, architecture, painting, literature can all be perverted from their high mission of elevation, to become powerful factors in degrading. Nature study cannot be anything but uplifting. The sunsets, the clouds, the woods, the fields, are always pure, and they willingly stretch out their hands to their admirers. If there is any response on our part it is always, "I would be as pure as you are pure." We can study science to sharpen intellect only, but we cannot have the true "nature study" without elevation of thought and refinement of life. We love nature by our best nature. Where there is the real love there is the real personal uplifting. Nature spreads her beautiful on every side and says, "Come and be beautiful with me."

Do not go with the child into the beautiful realms of nature, hoping to win him to something loftier and purer. Go because the child will win you, will make you purer and better. He is your master there. Heaven lies very

near to infancy and youth. It is not only the kingdom of heaven that must be received by the heart of the little child, but it is also the kingdom of earth. You have towered so long above him in your superior wisdom and experience, that the process of changing and of permitting the child to be superior, is sometimes painful, and sometimes excites rebellion.

The Point of View.

The authors of "Nature Study Lessons" have presented the reader with chapters covering a wide range. But are they not right? How can one tell what will appeal to the child, unless one presents to it a large variety. It is after all, not so much *what* is taken, but *how*. It is impossible to know everything, but it is possible to know some things so well and in such a spirit, as to lead to a love of every natural object.

But perhaps some specialist will say that a little of everything means nothing of anything; that the child should be made a specialist in a few things, and from such a point of view, from such an appreciation of what he has learned that he shall be lead, unconsciously to himself, to have an intuitional love and an active desire for a deeper knowledge of other things.

To my mind the point of preëminent excellence in "Nature Study Lessons" is the evident intention of the book to teach the child to know well, and from the right point of view, a few commonplace things, about which he already has a certain amount of information. This teaching is so systematized, so extended and made so virile, that the child must be quickened in thought, and broadened in his sympathy and in his affection for all nature.

The subjects chosen come within the child's everyday experience, or are such things as come easily within his reach.

The most readily accessible is the child's own body, and there is a peculiar significance in devoting the first chapter to that subject, and the first paragraph to "Its Beauty." This is from the true nature study standpoint, the ideal of the commonplace. It is easy to see this beauty—for beauty and love are correlatives—and what child does not love his own self.

From an appreciation of one's own organism, developed by a study of our various senses, the student is lead to an admiring knowledge of other organisms. Then the authors logically devote their next chapter to one of the child's nearest and most attractive pets. The succeeding sections are devoted to domestic animals and to familiar birds, beginning with an excellent account of the most available specimen in the domain of ornithology, the farm-yard hen.

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And all this, from the first chapter on "The Human Body" to the last on "The Lever and Fulcrum," is teaching the child the correct point of view; that is it is teaching him to see things in their details and in their varied relationships, rather than to glance at them casually. It tries to show him the harmony of nature; to help him to become a part of that harmony (and this is happiness), and to become a part of the truth, or as Tennyson has expressed it, "A part of all I have seen," thereby hastening the development of character, and this is the object of human life.

Happiness.

"Life, liberty and the pursuit of happiness." But who has learned how to pursue happiness successfully? Now you hold the phantom in full possession and know it not. Happiness? I hope to obtain it by and by, when leisure comes, when the home is built, when fame is achieved, when a fortune is amassed; and some of us put it all forward into the future life. Stop the mad, deceiving chase. Hold happiness now. You have it; all that you ever will have of it. Shall I say that you must try to realize it? No; for then it is gone.

But let us enjoy this paradise of common things. Then we can teach the child that this is a beautiful world. The Almighty pronounced it good. I do not believe that He has given us any better than His best work for our present capacity. We need not try to imagine anything better, till we have done our best to comprehend this.

It is the mission of nature study to give love, peace, happiness, and those are the ends of life. I cordially bid godspeed to "Nature Study Lessons" or to any other honest, sympathetic attempt to develop the child through nature and put him in closer touch with the means of life, liberty and the pursuit of happiness.

NATURE-STUDY LESSONS

I.—THE HUMAN BODY.

A. Its Beauty.

1. (*a*) Observe the bodies of your companions.
   (*b*) Examine your own when undressing.
   (*c*) Note the beautiful curves and the symmetry of form.
   (*d*) Try to find a curve on one side which is not repeated on the other.

B. Its Individuality.

2. (*a*) Observe the marked individuality of each human being.
   (*b*) Note the different complexions, the different colors of the hair, the different positions assumed by different persons in standing, in walking, in sitting, etc.

3. In the streets of towns observe, if you have the opportunity, people who are called Indians, Chinese, etc. Compare them with each other and with ourselves.

C. Its Divisions.

4. (*a*) Observe the four natural divisions of the body—head, trunk, upper extremities, lower extremities.
   (*b*) Discover how the head and extremities are joined to the trunk and the most apparent use of each.

5. Observe particularly the adaptibility of part to part, and of the whole body to its work.

6. The body will grow and strengthen through exercise. Note different kinds of exercise adapted to develop and strengthen different parts of the body.

The Head.

7. (*a*) Examine the head.
   (*b*) Note the different curves. Observe that the arch at the top gives strength.
   (*c*) Name the different parts and the special use of each.

8. (*a*) Observe the hair on different heads.
   (*b*) Note its different colors and textures.
   (*c*) How does it protect the head?
   (*d*) What are the other uses of hair?

9. (*a*) Slip a hair between the thumb and finger with a back and forward movement to discover the root-end of the hair.
   (*b*) If possible, examine a hair with a compound microscope to discover why it moves in only one direction when treated as in 9 (*a*).

10. (*a*) Examine different faces.
   (*b*) Note their shapes. Compare faces of people around you with those of different races of people if you have the opportunity.

11. Discover the parts of the head that you can move at will

12. What bones give the most marked outline to the face?

13. Name and give the position of the different parts of the face.

14. (*a*) Using a mirror, examine the inside of the mouth.
(*b*) Describe the parts observed.
(*c*) Make drawings of the parts and investigate the use of each.

The Trunk.

15. Observe its general shape.

16. Show the appropriateness of the name.

17. Describe its framework.

18. (*a*) Discover what prevents this part of the body from being jarred, for example, when one jumps from a fence.
(*b*) Examine the skeleton of the body if available.

The Upper Extremities.

19. Observe the three divisions (upper arm, fore-arm and hand) into which each of the arms naturally falls.

20. Move the arm in different ways. Feel the joints.

21. (*a*) Discover the different kinds of joints.
(*b*) Which joints act like a hinge?
(*c*) Which ones act like a ball in a socket?

22. Compare the parts of the upper limbs with the corresponding divisions of any of the domestic animals.

The Lower Extremities.

23. Observe the divisions of the lower limbs—thigh, leg and foot.

Practise the correct use of the names of the parts. Do not speak of the leg when you mean the thigh.

24. Discover how these parts are joined to one another.

25. Observe the way in which the different joints move.

26. Compare the knee-joint with the elbow-joint, and the hip-joint with the shoulder-joint.

27. Compare the divisions of the lower limbs with the corresponding divisions of the limbs of domestic animals.

The Foot.

28. Observe the divisions of the foot—the ankle, the heel, the sole, the arch or instep, and the toes.

29. Compare these parts with the corresponding parts of the hand.

30. (*a*) Examine the joints of the toes.

(*b*) Compare the number, position and movement of these joints with those of the fingers.

31. Examine the toe-nails. Infer their use.

32. Compare the divisions of the foot with the corresponding ones of the feet of domestic animals.

D. Its Covering.

33. Examine the skin and note the following:

(*a*) Its beauty.

(*b*) Its work.

(*c*) Why should it be kept clean?

E. How to Take Care of the Body.

34. In the lessons on Physiology and Hygiene try to learn by the Nature-Study method, the use and suitable means of bathing, nourishing, and clothing the body in different seasons of the year.

II.—FEELING.

A. Sense of Touch.

1. While the eyes are closed, try to distinguish objects by touching them; *e.g.*, an apple, an orange, sugar, a pen, a pair of scissors, different kinds of nuts, of leaves, of seeds.

2. Discover:

(*a*) The advantage in having all the parts of the body sensitive to touch.

(*b*) The parts of the body most sensitive to touch.

3. Discover where the sense of touch is most highly developed in the cow, the horse, the cat and the dog.

B. How to Cultivate the Sense of Touch.

4. Feel a number of objects of different degrees of smoothness and determine:

(*a*) The smoothest.

(*b*) The roughest.

(*c*) Two of the same degree of smoothness.

5. The teacher or someone else will place a number of objects of various shapes on the desk, each shape being represented by two or more objects. With eyes closed take one in your hand and find another of the same shape.

6. Place your hands behind your back; the teacher or someone else will put objects in them. Name these objects by feeling them.

7. Take thread and cord of various degrees of coarseness and discover by the sense of touch which is the finest, which the coarsest.

8. With eyes closed allow someone to lead you to various objects in the room. Name these objects by feeling them.

9. After the leaves of the more common trees have been studied, identify them by touch alone.

10. If possible, discover how a blind man learns to read.

III.—SEEING.

A. Sense of Sight.

1. (*a*) How many letters are there in this line?

(*b*) Can a blind person tell?

2. (*a*) How many panes of glass are there in the window?

(*b*) Can a blind person himself find out?

3. What sense did you use in answering questions 1 (*a*) and 2 (*a*)?

B. The Organ of Sight.

4. (*a*) Examine the eyes of different people.

(*b*) Observe their different colors.

5. Note the different parts of the eye.

6. Describe each part and, if you can, discover its use.

7. Draw an eye.

8. Observe the different means by which the eye is protected.

9. (*a*) Have your eyes ever felt tired?

(*b*) What caused them to feel tired?

10. What is the effect of looking towards a strong light, as the sun?

11. Infer some rules for the care of the eyes.

NOTE.—Through the breaking of a dark glass of his telescope, while looking at the sun, an astronomer lost the sight of one eye.

C. Light and Seeing.

12. (*a*) Close your eyes and tell what you can see.

(*b*) Cover the eyes with a handkerchief and tell what you can then see.

(*c*) Place a pane of glass before your eyes and tell what you can see.

(*d*) Why are objects seen indistinctly at night?

(*e*) Why are objects in a dark room not visible?

(*f*) By means of a mirror, throw light into a corner of a dark room.

(*g*) From these experiments, what do you find is necessary for seeing?

D. How to Train the Sense of Sight.

13. The teacher or someone else will :—

(*a*) Hold for an instant a number of articles before the class. The pupil will tell how many there are and their names in order.

(*b*) For a moment expose a combination of letters not making a word upon the blackboard and have the number of letters in it given.

(*c*) Put a column of letters upon the board covered with a card or screen, withdraw the covering for a definite time, as a second or two, and have their number told.

14. Observe and name objects on the way to and from school.

15. Observe the shape of different houses and sketch one from memory. Compare your sketch with one made while looking at the house.

16. While the memory is still fresh, write lists of things observed under the following headings :—

(*a*) Flowers.

(*b*) Trees.

(*c*) Animals.

17. Discover from these experiments the effect of attention upon seeing.

IV.—HEARING.

A. How Sound Travels.

1. Have someone strike the end of the table while you listen at the other end. Note the effect.

2. With a pin or nail scratch the end of a ruler or long pointer while the other end is held against your ear. Note the effect.

3. Fasten a silver spoon to the middle of a string. Put an end of the string in each ear. Then slightly swing the spoon until it touches the edge of the table. Note the effect.

4. Procure two opened cylindrical fruit-cans. Pierce a hole in the bottom of each. Connect the cans with a string or wire by passing it through the holes and fastening it on the inside. Have someone speak into one of the cans; listen with the other at the ear and note the result.

5. In each of the above cases observe the following:—
   (*a*) The point at which the sound was produced.
   (*b*) The distance at which the sound was heard.
   (*c*) How the sound reached the ear.

6. (*a*) Infer whether sound is conveyed more readily through air or through a solid.
   (*b*) Infer the use of wire used in telephoning.

B. Vibrations of Sound.

7. (*a*) Strike a tuning-fork against the table. Observe it with the eye and state what you discover.
   (*b*) Strike it again and touch one of the prongs slightly. Note what you observe. (Lacking a tuning-fork, you may use any other kind of steel fork,—a pitch-fork will do.)

8. (*a*) Fix a flexible steel needle firmly in a cork which will give it sufficient support. Then fasten at the upper extremity a ball of wax, or a piece of paper, or pith, or cork, about the size of a pea. Hold the cork firmly in one hand and strike the needle till you cause it to vibrate. Describe the movements of the wax or paper.
   (*b*) Strike the needle with greater force and state what you observe.

9. Throw a stone into the water and observe the effect.

10. Infer from the above experiments the nature of vibrations.

11. Note also that the wave-vibrations grow less and less until they die away altogether.

C. Vibrations can be Collected.

12. Observe whether the sound of the voice can be heard better in a building or in the open air.

13. Infer the reason.

14. (*a*) Observe the shape of the ears of certain animals that discover their prey by hearing.
(*b*) Infer the purpose of the shape.

15. (*a*) Place the hand behind the ear.
(*b*) Listen to different sounds.
(*c*) Note the effect of alternately removing and returning the hand.

16. (*a*) If you have the opportunity, examine an ear-trumpet.
(*b*) Infer why it is thus formed.

D. Time Necessary for Sound to Travel.

17. (*a*) Observe a carpenter some distance from you driving a nail. Is the sound heard at the time you see the hammer strike the nail?
(*b*) A train is approaching a crossing. You see the steam from the whistle of the engine. When do you hear the whistle?
(*c*) You see a flash of lightning. Is the thunder always heard at once?
(*d*) From these observations, what inference as to time can you make with regard to the vibration of air?

(*e*) Try to verify the statement that sound travels about 1120 ft. per second.

(*f*) Calculate the distance of the engine or of the flash of lightning referred to above.

E. The Organ of Hearing.

18. (*a*) Examine the outer ear.

(*b*) Observe the adaptation of its form.

(*c*) Note the entrance to the inner ear and how the entrance is protected.

(*d*) Describe the ear, noting in your description each of the above points. Illustrate your description by drawings.

19. What is the use of each part of the ear?

20. If possible, examine the receiver of a telephone and compare its parts with those of the ear.

F. Attention and Hearing.

21. (*a*) Why is one in a room where a clock is going not always conscious of its ticking?

(*b*) Give heed to all the sounds you can hear in a minute and make a list of them.

(*c*) Why do you not always hear all the sounds?

G. How to Train the Sense of Hearing.

22. (*a*) Distinguish different birds by their notes.

(*b*) Examine several objects of different weights and different degrees of hardness, then, by listening to the sound that each makes when it is dropped on the floor by the teacher, tell what it is.

(*c*) With eyes closed, recognize different companions by their utterance of a word.

(*d*) Distinguish different kinds of whistles, as of locomotives, threshing engines.

(*e*) Endeavor to distinguish different sounds.

V.—TASTING.

A. Sense of Taste.

1. Try to distinguish by the sense of taste different things, such as sugar, salt, oatmeal, tea, soap, tar, sweet apples, sour apples, etc.

B. Organ of Taste.

2. Discover what parts of the tongue are most susceptible to impressions made by different substances taken into the mouth.

3. On what part of the tongue can you best taste sugar? salt?

4. (*a*) Wipe the tongue dry and then try to taste dry sugar or salt.

(*b*) What inference can you make from this experiment?

5. Draw the tongue.

C. Uses of Taste.

6. Observe how different species of fruits are selected by buyers.

7. What may determine the mixture of materials used in cooking besides the actual food value?

8. Observe the way in which purchasers of butter and cheese determine the quality of these articles.

9. How do animals select their food?

10. Compare different kinds of acid substances by tasting them.

11. Compare, similarly, different kinds of sweet substances; of bitter substances; of pungent substances.

12. Make a list of different tastes you have observed and name a substance by which each taste has been excited.

13. Note the enjoyment we gain from eating that which pleases our taste.

NOTE.—Sugar is sweet, common salt is salty or saline, sea-water is brackish, pepper is pungent, alum is astringent, vinegar is sour or acid, quinine is bitter, 'wild-turnip' is acrid, turpentine is terebinthine, onion or garlic is alliaceous, meal is farinaceous. The tastes of many substances are named by reference to the tastes of other well-known substances; hence, we say 'oily,' 'cheesy,' 'fishy,' 'like radish,' 'like mint,' 'like lemons.' Many of the so-called tastes are combinations of taste, smell, and feeling.

VI.—SMELLING.

A. Sense of Smell.

1. You have two unlabelled bottles, one of turpentine and the other of water. How can you tell which each is?

2. With eyes closed, try to name certain things used for food—sugar, dried fruit, oatmeal, onions, oranges, toast.

3. By the sense of smell alone, try to distinguish certain flowers.

B. Organ of Smell.

4. Observe the nose and note its parts.

5. The nose is of what other use than as an organ of smell?

6. What advantage is it that the nerves of smell are in the respiratory path?

7. Note that the bottle of turpentine in No. 1 must be uncorked to allow a part of the turpentine to escape.

The most powerful microscope is unable to reveal the fine particles that touch the sense of smell. You smell a flower. The fragrance is agreeable, but you cannot see it. The fragrance is really due to very fine particles floating about in the air, and going with it into the nostrils. There are a great many folds in the nose, which present a great deal of surface to the fine particles. In the lining of the nose are very fine nerves. The little particles stimulate the nerves. The nerves convey the stimulus to the brain. The mind then knows it as a sensation of smell.

C. Uses of Smell.

8. How are you enabled to detect the presence of coal gas in a house?

9. How can you determine on entering a room whether it has been recently ventilated?

10. Infer of what special value the sense of smell is to man.

11. Give other examples in which the sense of smell protects man.

12. Why do persons use perfume?

13. What are the uses of the sense of smell?

D. Sense of Smell in Inferior Animals.

14. Observe how the different animals make use of this sense.

(*a*) Why are flowers odorous?

(*b*) How are insects guided to flowers?

(*c*) How does a dog search out his master?

(*d*) How do some dogs follow rabbits, deer and other animals of the chase?

(*e*) Account for the position in which a dog holds his head while hunting.

(*f*) How do crows and other carrion birds know where a dead animal lies?

E. How to Train the Sense of Smell.

15. Examine such objects as the following and observe their odors:—Apples, pears, oranges, lemons, pineapples, pepper, celery seed, caraway, sage, etc.

16. With closed eyes name objects by smelling them, as ginger, lemon, pepper, camphor.

17. With eyes closed determine the names of flowers and plants by their odor.

18. Name the substances kept in unlabelled vials.

The teacher may put peppermint and other essences, rose and other perfumes, turpentine and other oils, etc., in vials to be kept in the school-room and used for sense-training.

VII.—THE HAND.

A. General Appearance.

1. Examine your hand closely.

2. How is it connected with the arm?

3. Move the hand in as many directions as you can while keeping the arm at rest.

4. In how many directions can you move your hand?

5. Infer the purpose of the wrist.

6. By feeling carefully the wrist of one hand between the thumb and fingers of the other, meanwhile moving the former hand in different directions, discover how the structure of the wrist is adapted to the various movements of the hand.

7. Describe the part of the hand joined to the wrist.

8. Compare the back and front of this part as to form.

9. Account for this difference in form by reference to their respective uses.

B. Its Skin.

10. (*a*) Compare the appearance of the skin in the front (palm) of this part with that on the back of it.

(*b*) Compare the movability of the latter with that of the former.

(*c*) Which is the thicker?

(*d*) Discover the purpose in this difference.

(*e*) What effect has work on the palm of the hand?

(*f*) What causes blisters?

(*g*) Observe the wrinkles in the skin on the back of the joints and account for them.

11. Describe the markings on the palm.

12. Observe the palm as you close the hand and discover the cause of these lines and of their directions.

13. Compare the back of the hand with the palm in respect to hairiness.

14. With a good magnifying lens try to observe the numerous minute pits which are the mouths of the sweat pores. These may be seen in the skin of the palm.

C. Its Bones.

15. Feel the back of the broad part of the hand with the fingers of the other hand to discover the nature of the framework.

16. What forms this framework?

17. (*a*) How many bones can you feel in the framework?

(*b*) Describe their shape.

(*c*) How do they compare in number with the number of fingers and thumb?

(*d*) Compare these five bones as to length.

(*e*) Can you feel them on the palm as easily as on the back? If not, why?

(*f*) Infer on which side of the hand the bones are nearer the surface and discover the advantage in this.

D. The Fingers.

18. Examine the connection of these bones with the bones of the fingers and thumb.

19. (*a*) Pick up any small object such as a pin or a bead from the desk.

(*b*) Describe the way you do it.

(*c*) Now, try to pick up the same object by using the fingers without the thumb.

(*d*) Place the thumb opposite each finger in turn.

(*e*) Discover the advantage of being able to place the thumb opposite each finger.

20. How many bones are there in each finger? How many in the thumb?

21. In respect to the number of bones, compare the thumb and fingers with the great toe and small toes respectively.

22. (*a*) Shut the hand or grasp a small, round stick and observe the position of the thumb and fingers.

(*b*) Note how the hand is adapted to the work of grasping.

(*c*) How would the power of grasping be affected by each finger having only one bone?

23. Describe the joints where the fingers are attached to the large part of the hand.

These joints are called *knuckles*.

24. (*a*) Compare the size of the bone at the joint with its size near the middle.

(*b*) Discover the advantage of the enlargement of the bone at the joint.

25. In how many directions can you move the fingers at the knuckles?

26. Observe in what directions you can move the parts of the fingers beyond each of the joints.

27. Infer the advantage in the difference of movements of the joints.

28. Name other joints in the body that have the same movement as the knuckles.

29. Name other joints in the body similar in movement to those of the fingers.

30. (*a*) Describe the nails.
(*b*) Infer their use.
(*c*) Observe the areas shown by different colors in the nails.
(*d*) Why does it hurt to wound the nail at its base and not to pare it at the outer end?

31. (*a*) What parts of the foot of the horse, the cow, the dog, the cat, and the hen, respectively, correspond to the nails?
(*b*) Compare each in shape and use with the nails.

E. The Circulation.

32. Trace the veins in your wrist and hand or observe them in an aged person's hands.

33. (*a*) Count the pulsations in the artery in the wrist.
(*b*) Try to feel the pulse in the middle of your palm.
(*c*) Place your hands in such position that you can feel the wrist pulse of your left hand with the thumb of your right hand and your heart beat at the same time with the fingers of your right hand. From this experiment infer the cause of the pulse.

VIII.—THE CAT.

Observe the cat at your home. Notice how it eats and drinks; its playfulness; its gentleness; its fondness for those who care for it; its various movements, as walking, springing, and climbing; its fondness for a cosy spot; the sounds it makes and on what occasions; its treatment of its young; its favorite positions when it sleeps, when it watches for its prey, etc.

A. Its Food and Drink.

1. (*a*) What kind of food and drink does the cat like?
(*b*) How does it get meat off a bone?
(*c*) How does it drink milk?
(*d*) Compare it with the dog in these respects.

B. Its Mouth, Teeth and Tongue.

2. (*a*) Notice how far back its mouth is extended.
   (*b*) What advantage is this extension to the cat?
3. (*a*) Examine the teeth and infer the purpose of the four long ones near the front of the mouth.
   (*b*) Note the suitability of its teeth for grinding food.
4. Draw the open mouth of a cat.
5. (*a*) Examine the tongue.
   (*b*) Use a lens or the finger to discover the roughness of the tongue.
   (*c*) Give the cat a bone with very little meat on it; observe it eating and infer the use of the roughness of the tongue to the cat.
6. Draw the tongue.

C. Its Eyes and Eyesight.

7. (*a*) Examine the eyes—note the lids and the shape of the pupil in light and in darkness.
   (*b*) Shut a cat up for a short time in a dark place and observe the eyes on being brought into the light and for a short time afterwards.
   (*c*) What change has taken place in the pupil of the eye?
   (*d*) Infer the use of the enlarged pupil in the dark.
8. Draw the eye as it appears:
   (*a*) In a strong light.
   (*b*) In a dim light.

D. Its Whiskers and Feeling.

9. Touch the whiskers of the cat and observe how sensitive they are.

10. Trail a piece of meat tied to a string along the floor, and observe how the cat carries its head when following it; also the position of the whiskers.

11. Infer the use of the whiskers to the cat.

E. Its Ears and Hearing.

12. (*a*) Examine the ears.
    (*b*) Note their shape and position.
    (*c*) What advantage does their position confer?

13. (*a*) Scratch with a pin near the cat.
    (*b*) Observe its actions.
    (*c*) Note the position of its ears while listening.
    (*d*) Discover whether its hearing is acute.

F. Its Feet and Claws.

14. (*a*) Examine the feet.
    (*b*) Describe them, pointing out the number of the toes on each foot, the number of claws, where these are situated, and their shape.
    (*c*) Discover the use made of the claws, and why they can be kept so sharp.

15. Compare the feet of the cat with those of the dog. What differences in mode of life are suited to these differences in the structure of the foot?

16. How is it that the cat can walk so noiselessly?

17. Place the cat on the side of a post or tree and describe its method of climbing.

G. Its Legs and Joints.

18. (*a*) Examine the legs.
    (*b*) Notice how the fore legs are hinged to the body.
    (*c*) Observe the great flexibility of all the joints and infer the purpose.

(*d*) In what position is the fore leg when the paw is on the ground?

(*e*) Draw it in this position.

(*f*) Infer the effect of this position upon the movements of the cat.

19. Cause the cat to jump from a table or to spring upon an object, and observe:

(*a*) The use it makes of the hind legs.

(*b*) How it alights.

(*c*) The ease with which it jumps.

20. (*a*) Trail a ball along the floor and observe the position of the cat as it creeps after it.

(*b*) Observe closely and describe the following:—

(1) The position of the body.

(2) The movements of the legs as it steals forward.

(3) How it springs.

(4) How it grasps the ball.

21. Discover if possible why cats are attracted by moving objects.

H. Its Prey.

22. If possible observe the cat watching a mouse or hunting a bird.

23. Discover upon what the cat preys.

24. Observe how it catches its prey and how it treats the prey after catching it.

25. Point out how the legs, the claws and the teeth of cats are specially adapted to their habits.

I. Its Covering.

26. (*a*) Examine the covering of the cat; compare it with that of the dog.

(*b*) What is the difference between the outside part and that next to the body of the cat?

27. Discover why the woolly part next the body takes so long to dry after being wet.

28. Infer why the cat dislikes water.

29. Notice the change in the covering during the early summer.

30. Infer the reason for the change.

J. The Kitten.

31. Observe how the cat treats its kittens:—

(*a*) When nursing them.

(*b*) When training them.

(*c*) When washing them.

(*d*) When protecting them from danger, as from dogs.

(*e*) When carrying them.

32. What signs of courage and affection have you observed in the cat while caring for its young?

33. Account for its carrying its kittens from one place to another.

K. Its Language.

34. (*a*) Observe the sounds made by the cat when contented and comfortable; imitate the sound.

(*b*) Note how the cat asks questions; imitate this sound.

(*c*) Observe it when angry and imitate the sound.

L. Washing and Sleeping.

35. (*a*) Observe a cat after eating.

(*b*) Describe how it cleans itself.

36. (*a*) Observe it when asleep and note how it places its paws, its tail and its head.
(*b*) Discover whether it is a sound sleeper or not.
(*c*) Note the places it selects for a sleep.
(*d*) Infer whether the cat is fond of warmth or not.

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37. Write a composition on "the Cat" according to the direction of the teacher. Illustrate it as freely as you can.

IX.—THE DOMESTIC RABBIT.

Observe rabbits at the homes of those who keep them, or in the school-yard, if any are kept there. Observe wild ones in the woods and pastures, if you have the opportunity.

A. Its Food.

1. (*a*) Discover what kind of food the rabbit relishes. Try grasses, carrot-tops, cabbage-leaves, lettuce, carrots, the stumps of cabbage, turnips, grain, fresh branches of trees, etc.
(*b*) At what time of the day do they feed most freely?

2. (*a*) Discover what the rabbit likes to drink.
(*b*) Describe how it drinks and compare its manner of drinking with that of the cat.

B. Its Home.

3. Why are the rabbits kept in a house or cage?

4. (*a*) Allow them freedom and observe their movements.
(*b*) Where do they hide themselves?
(*c*) Notice how they burrow.

5. Describe how they remove the earth, noting the use made of the fore feet and of the hind ones.

C. Its Movements.

6. (*a*) Watch the rabbit in its cage where there is little room to move about.
   (*b*) How does it move its legs in *walking?*
   (*c*) Compare this movement with that of the cat.
   (*d*) Let the rabbit loose in a room or yard.
   (*e*) Observe how it moves when not frightened.
   (*f*) Describe how it *hops.*
   (*g*) Frighten the rabbit when it is in the yard.
   (*h*) Notice how it *jumps.*
   (*i*) Describe the movement of the hind legs when in the act of jumping.
   (*j*) If possible, notice the marks made by its feet as it alights, and draw them.
   (*k*) How far can it jump?
7. (*a*) How many ways has the rabbit of going from place to place?
   (*b*) Discover which is its favorite way.

D. Its Structure.

The Head.

8. Notice the shape of the head and its size.
9. (*a*) Where are the ears on the head?
   (*b*) Compare with the position of the ears of a cat.
   (*c*) Measure the length of the ear and compare its size with the ear of a cat.
   (*d*) Note how the rabbit uses its ears when listening.
   (*e*) Discover whether its hearing is acute and infer the resulting habits.

10. (*a*) Describe the position of the eyes.
(*b*) Infer the advantage to the rabbit of this position.
(*c*) Observe how the rabbit turns its eyes when a noise is made behind it.

11. Discover whether its eyesight is keen. Compare it with the cat in this respect.

12. Are the eyes of all rabbits that you have observed of the same color?

13. (*a*) Note the position of the nose.
(*b*) How are the nostrils separated?
(*c*) Discover why the nostrils are in such constant motion.

14. (*a*) Where are the whiskers placed?
(*b*) Compare their position and length with those of the cat.

15. (*a*) Observe the lips.
(*b*) Note any peculiarities of the lips.

When there is a fissure in the upper lip like that of the rabbit, the lip is called a hare-lip.

16. (*a*) Observe the different movements of the jaws.
(*b*) How many movements has the upper jaw?
(*c*) Describe the various movements of the lower jaw.
(*d*) Infer the use of each movement.

17. (*a*) Examine the teeth of a rabbit.
(*b*) Compare with the teeth of a cat and of a child.

18. (*a*) How many long chisel-shaped teeth are there in each jaw?
(*b*) What kind of teeth is next to these teeth?

19. (*a*) Where are the broad, flat teeth placed?
(*b*) How many of these are there in each jaw?

20. Infer the use of each kind of teeth.

21. Observe the rabbit eating a carrot or cabbage-leaf and infer the purpose of the cleft upper-lip.

22. (*a*) With a file, test an incisor tooth of a dead rabbit and ascertain which is the harder part of the tooth, the front part or the back part.

(*b*) Infer from this how gnawing tends to keep these teeth sharp.

23. Draw the head.

Its Feet and Legs.

24. Note the position and size of the fore legs; also of the hind legs.

25. Compare the size and range of motion of the fore and hind legs.

26. How many toes are on the fore foot?

27. Describe and make drawings of a fore foot and a fore leg.

28. Describe and make drawings of each part of a hind leg.

29. Infer why the rabbit can jump so well.

30. (*a*) Describe a hind foot.

(*b*) Compare it with the fore foot.

(*c*) Compare it with the hind foot of a cat.

31. Infer how rabbits walk so noiselessly; also how they walk so well upon soft snow.

32. Note the number and position of the joints in each leg.

33. Compare these joints with those of the cat and grasshopper.

The Body and its Covering.

34. (*a*) What is the shape of the body?
    (*b*) Compare its size with that of a full-grown cat.
35. (*a*) Notice the covering.
    (*b*) Describe it.
    (*c*) Is there any part without fur?

E. Its Habits and Disposition.

36. (*a*) Observe the rabbit when lying down. Note the position assumed.
    (*b*) How are the legs placed?
    (*c*) How does it hold its ears then?
    (*d*) Are the eyes tightly closed when asleep?
    (*e*) Compare its way of sleeping with that of a cat or dog.
    (*f*) Draw it when it is asleep.
37. (*a*) Observe its position when sitting.
    (*b*) Draw it in this position.
38. (*a*) Observe the rabbit clean itself.
    (*b*) Describe how it washes itself.
    (*c*) Compare its mode of washing with that of the cat.
39. (*a*) Observe a number of rabbits together.
    (*b*) Note what they do to and for one another.
    (*c*) Note whether they are gentle or rough.
40. (*a*) Give one a cabbage-leaf.
    (*b*) Note whether it is selfish.
41. (*a*) From their general way of acting infer whether they are bold or timid.
    (*b*) Infer whether they appreciate kindness.

42. (*a*) Observe them playing together.
(*b*) Describe their actions while playing.
(*c*) Infer whether the rabbit is inclined to be social or otherwise.

43. (*a*) How does the rabbit produce the sound called "thumping"?
(*b*) Why does it "thump"?

After you have made the above studies by your own observation, and are thus prepared to write compositions on the rabbit, look at pictures of rabbit-life and read stories about rabbits. A good rabbit-story is Raggylug in "Wild Animals I Have Known." There are good rabbit-stories in "Uncle Remus."

X.—THE COW.

A. General Build.

1. Observe a cow and describe her general appearance, color, shape and size.

2. How does she compare with the horse in:
(*a*) Size.
(*b*) Shape of body.
(*c*) Length of neck.
(*d*) Size of head.
(*e*) Covering of body.
(*f*) The tail.

B. The Cow Feeding.

3. (*a*) From your observation of cows in the field, what forms their chief food?
(*b*) Name other animals you have seen using the same kind of food.
(*c*) From what you know of the cow's food, infer what sort of country would be most suitable for her maintenance throughout the year.

4. (*a*) Observe the cow in the pasture-field and note carefully how she gathers the grass.
(*b*) Describe the movement of the tongue.
(*c*) What is the purpose of this movement?
(*d*) With what parts of the mouth does she seize the grass?
(*e*) Describe the motion of the head while the animal is feeding.
(*f*) Why does she move her head in this way?
(*g*) From this infer whether the cow bites off the grass or pulls it.

5. Compare the positions of the front legs of the cow and of the horse while these animals are feeding in the field, and account for the difference.

C. The Head.

6. Describe its shape.
7. (*a*) From what part of the head do the horns grow?
(*b*) What is their shape?
(*c*) Compare the horns of the cow with those of the sheep, the goat and the deer, as to position, size and shape.
8. (*a*) When an opportunity offers observe the position and attitude of body the cow takes on meeting a strange cow or when attacked by a dog.
(*b*) Infer the purpose of the horns.
(*c*) Compare her modes of defence with those of the horse.
9. (*a*) Where are the eyes placed?
(*b*) Make a drawing of the eye, natural size.
(*c*) Describe the "look" of the eyes.
(*d*) What disposition in the animal does this indicate?

10. (*a*) Describe the ears as to position, size, shape and covering.

(*b*) Are the ears movable?

(*c*) Compare with your own in this respect; also with those of the horse, sheep, rabbit, deer.

(*d*) What good purpose is served by this power to move the ears?

11. (*a*) Visit a butcher's shop and examine the skull of the cow.

(*b*) Where are the teeth placed?

(*c*) Compare the teeth of the upper jaw with those of the lower as to shape and position.

(*d*) How do the front teeth of the lower jaw differ from the back teeth of both jaws?

12. From your knowledge of the mouth of the cow tell exactly how the grass is held when it is pulled.

13. What is the substitute for front teeth in the upper jaw?

14. From the shapes of the front and back teeth in the cow infer their special uses.

15. Compare the teeth of the cow with those of other animals—if they can be had—with those of the sheep, the horse, the hog; also with those of the rabbit, cat and dog.

16. Observe these different animals in a field and account for the similarity or difference in their mode of feeding by reference to the similarity or difference in the position and kind of teeth.

17. An eminent zoologist from a tooth alone made a very good description of a kind of animal that he had never seen. How is it that the teeth can suggest so much respecting the size, form and habits of an animal?

18. Examine the teeth of animals to discover the appropriateness of the names incisors, cuspids, bicuspids, molars.

19. The dental formula shows the number and arrangement of the different kinds of teeth that an animal has. That of the adult man is $\frac{2-1-2-3}{2-1-2-3}$. These numbers show that from the middle of the front the upper jaw has 2 incisors, 1 cuspid, 2 bicuspids and 3 molars, the lower jaw the same. Write the dental formula of the cow and other animals.

D. The Legs and Feet.

20. Examine and describe the legs of the cow as to size and length.

21. (*a*) Examine the feet.
(*b*) Describe their covering.
(*c*) How many toes are there on each foot?
(*d*) How do these toes differ as to size?
(*e*) How many toes on each foot press the ground in walking?
(*f*) Describe the action of the two large toes of each foot in walking.

22. What is the effect of this when the cow walks in soft soil?

A foot covered as that of the cow with such a hard, horny substance is called a *hoof*, and when the hoof is cleft or divided is said to be *cloven*.

23. Compare the hoof of the cow with that of other hoofed animals, as the horse, the sheep, the goat, the hog, the deer.

24. Observe a sheep or a goat walking, and note whether the hoof cleaves widely at each step as in the cow.

25. If possible, note the position in which sheep and goats like most to live and feed, and compare with that of the cow.

26. Account for the difference in the cleavage of the hoofs of the sheep and of the cow by reference to these conditions of environment.

27. (*a*) On what part of the foot does the cow walk?
(*b*) Compare this method of walking with that of man; of the horse; of the sheep; of the cat; of the dog.

28. (*a*) Where are the knees of the cow situated?
(*b*) Where are the ankles?
(*c*) Why do you think such joints are the knees and ankles respectively?

29. How does the knee in the cow and horse compare with that of man as to bending?

E. The Tail.

30. (*a*) Describe the tail of the cow as to length and covering.
(*b*) Compare it with that of the horse, the sheep, the deer, the hog, and the goat.
(*c*) Watch the cow in summer and note the use it makes of its tail.

31. Account, if possible, for the tails of the cow and horse being relatively much longer than those of the goat and the deer.

F. Mode of Lying Down and Rising Up.

32. (*a*) How does the cow lie down?
(*b*) Note all her movements and their order in this act.

33. (*a*) How does the cow rise?
    (*b*) Is the sequence of movements the same as in the action of lying down?
    (*c*) Describe these movements in the order of their occurrence.
34. (*a*) Observe the way in which the horse lies down.
    (*b*) Compare its motions with those of the cow in a similar act.
35. (*a*) How does the horse rise up?
    (*b*) Compare with a similar act of the cow.
    (*c*) Account for any difference in methods of rising from the position of rest by reference to their special means of defence.

G. Further Study of the Cow Feeding.

36. (*a*) What immediately becomes of the grass pulled by the cow in eating?
    (*b*) Note what takes place in your own mouth on taking a bite of bread or of meat.
    (*c*) What is the difference?
37. (*a*) Compare the feeding of the horse with that of the cow, as to the immediate disposition of the collected grass.
    (*b*) Account for this difference between the cow and the horse.
    (*c*) Compare similarly the cow and the sheep.
38. (*a*) What is the cow usually doing while lying down or while standing but not collecting grass?
    (*b*) Describe the movements of the jaws.
    (*c*) From your knowledge of the nature of the back teeth determine the purpose of the action.

This action of the cow is called *chewing the cud.* The cow stows away the grass as it is collected in a large receptacle called the *paunch.* From the paunch the mass passes into a second and smaller receptacle or stomach in which it is rolled into balls called *cuds.* By a muscular movement these cuds are, at a convenient time, brought up to the mouth and masticated and thence passed into a third receptacle whence they find their way into a fourth receptacle, the true stomach, where they are digested.

This method of quickly stowing away in a paunch a large amount of food without the necessity of masticating it at the time must have served an important purpose to the cow in its wild state as it serves the deer and other wild animals at present. It permitted them to gather much food in the grassy plains before being molested by predaceous animals like the tiger and lion. When satisfied or disturbed the cows retired to their coverts and chewed their cuds at leisure.

Animals that chew the cud as the cow are called *ruminants.*

39. (*a*) Name other ruminants that you have observed.

(*b*) Discover to what extent rumination is associated with the cloven hoof.

40. (*a*) Observe the cow drinking.

(*b*) Compare the drinking of the cow with that of the horse.

(*c*) Note the number of times a cow drinks and infer the advantage of having a running stream in the pasture field.

H. Uses of the Cow.

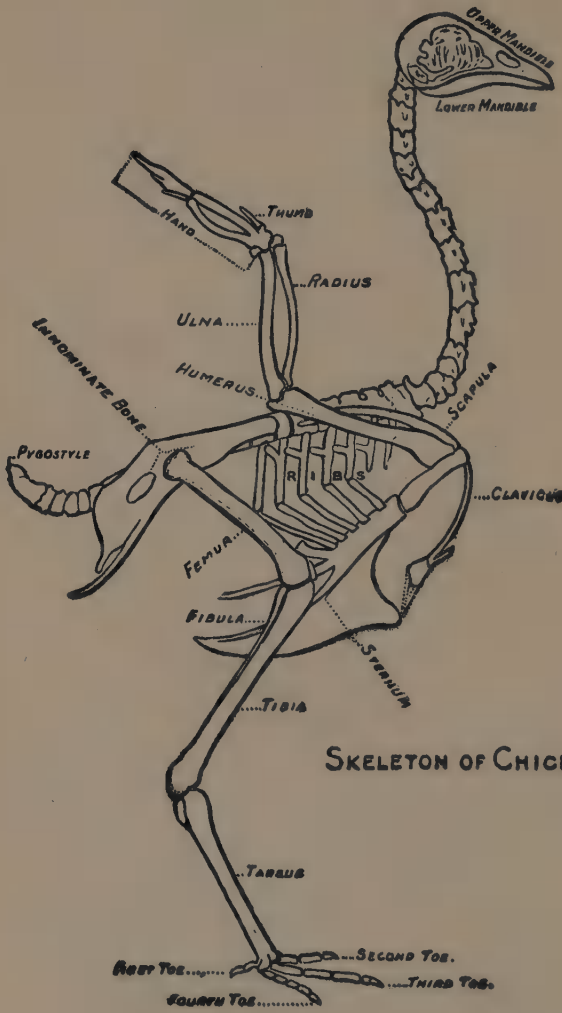
41. (*a*) What useful product is obtained directly from the living cow?

(*b*) How is it obtained?

(*c*) What products are made from it?

42. What uses are made of the different parts of the cow's body?

43. Compare the uses made of the covering of the cow with that of the horse and sheep.



SKELETON OF CHICKEN.

XI.—THE HEN.

A. Eating.

1. (*a*) Discover what kinds of food the hen likes.
   (*b*) Feed her grain, bread, bits of meat, and observe her finding food for herself or her chickens.
2. (*a*) How does she get food out of the ground?
   (*b*) Infer her use in this respect to the farmer.
3. (*a*) Examine the bill of the hen to discover how it is adapted to pick up grain.
   (*b*) Describe the bill and draw it.
4. Discover whether the hen has teeth.
5. Discover why the hen picks up and swallows coarse bits of gravel and small pebbles.
6. (*a*) When a fowl is "drawn" at home, examine its gizzard. Note the thickness of the walls.
   (*b*) From grinding a few grains of wheat between two flat stones, infer the use of the gizzard and the small pebbles which it contains.
7. Examine the crop and infer its use.

B. Drinking.

8. (*a*) Give the hen some water and observe how she drinks.
   (*b*) Why does she raise her head when she drinks?

C. The Covering.

9. (*a*) Select feathers from different parts of the body.
   (*b*) Observe and describe a large quill-feather from the wing.

A feather is composed of a hollow, horny stem, the *quill*, which passes into a four-sided shaft filled with pith, the *central axis*.

On each side of the central shaft are the *barbs*, which, in turn, bear *barbules* that interlock with the opposed barbules by means of small teeth. The central shaft and barbs of a feather are called the *vane*.

Study the barbules, if you have the opportunity, with a good lens or microscope and make drawings of what you observe.

10. (*a*) Compare a *down*-feather with a *quill*-feather.
(*b*) Discover the chief difference and infer the purpose of this difference.

11. Observe the feathers lying about the hennery, to discover when they are most numerous.

12. Discover whether a hen ever plucks her own feathers out.

When a hen sheds her feathers she is said *to molt*.

13. Catch a hen that is done molting and observe the new feathers growing.

The rudimentary feathers, before the vanes have expanded, are the *pin-feathers*.

14. Compare the molting of a hen with the change of covering of a cat, or a dog, or a snake.

D. Care of the Feathers.

15. (*a*) Discover how the hen cleans her feathers.
(*b*) Describe her actions when doing this.

16. (*a*) Pour water on a hen, discover whether her feathers are waterproof and infer why water runs off the hen.
(*b*) Observe the general arrangement of the feathers and infer the purposes.

E. Flight.

17. (*a*) Observe how a hen gets on her roost.
(*b*) Frighten her and observe her fly.
(*c*) Describe the position of the wings in the act of flying.
(*d*) Observe the arrangement of the feathers in the wings and infer their use in flying.

F. Feet.

18. (*a*) Examine the feet of a hen.
    (*b*) Describe these as to shape, position of the toes, number of toes, protection of toes.
    (*c*) Draw the foot.
    (*d*) Observe the hen while walking, scratching and roosting, in order to note the position of the toes in each of these actions.

19. (*a*) Examine the leg of a hen and discover why she does not fall off her roost when asleep.
    (*b*) Compare the hen in this respect with a caged canary or robin.
    (*c*) Draw the bones of the leg and show the position of the ligament which bends the toes when the weight of the body rests on the bent leg.

G. Hearing.

20. (*a*) How do you know a hen can hear?
    (*b*) Examine the head of a hen to discover her ears
    (*c*) Describe their position and appearance.

H. Smelling.

21. Observe the apertures on the upper bill and from their position infer their use.

I. Seeing.

22. (*a*) Examine the eyes and discover the number of lids, and their position.
    (*b*) Describe and draw an eye.

J. The Language of the Hen.

23. Observe sounds made by the hen :—
    (*a*) When she calls her chickens for food.
    (*b*) When she is quieting them folded into her breast by her wings.

(*c*) When she has laid an egg.
(*d*) When she is disturbed on her nest.
(*e*) When a cat or dog is interfering with her chickens.

24. Imitate the various sounds made by the hen.

K. The Nest.

25. Observe a hen's nest; notice where it is built, the material of which it is made, the use to which it is put.

L. The Egg.

26. (*a*) Observe the shape and size of hen's eggs.
(*b*) Draw an egg.
(*c*) From noticing their position in a nest infer the advantage of the eggs being oval.
(*d*) Carefully remove the shell from a part of the egg and observe the number of linings.
(*e*) Note the contents and their position.

The white part of the egg is the *albumen*. The yellow part is the *yolk*.

27. (*a*) Observe a small white spot on the upper side of the yolk and by examining eggs which have been set under the hen for various times note the change in this white spot as the hatching goes on.
(*b*) Infer what it is.

28. (*a*) When the chick breaks out of the shell, compare its covering with that of the hen.
(*b*) Observe how the mother-hen feeds it and how she defends it.

M. The Uses.

29. State the uses of the hen to man:
(*a*) When alive.
(*b*) When dead.

XII.—THE ROBIN.

The robin is one of the earliest birds to return after the long winter. Watch for its return and note the characteristics of this interesting bird.

A. Its Return.

1. (*a*) Make a record of the first appearance of the robin in the spring.

   (*b*) Compare it with the times at which other birds arrive.

2. Describe the markings of this bird.

3. Where does the one to arrive first seclude itself until the coming of its mate?

4. (*a*) Note the song of the robin on its return.

   (*b*) Imitate it.

   (*c*) Infer from it and its actions whether it is glad to return to its home.

5. (*a*) In what kind of trees or bushes do robins shelter themselves on their return?

   (*b*) Infer the reason for this choice.

B. Its Food.

6. (*a*) Discover what the robin eats.

   (*b*) Infer why gardeners at times welcome the robin, and again drive it away.

C. Its Appearance and Structure.

7. (*a*) How long is the robin from the tip of its beak to the end of its tail?

   (*b*) How tall is it as it stands erect?

8. Observe its head. Note the length of its bill, the position of its eyes and ears.

9. From the way it finds its food infer whether it has keen sight or not.

10. (*a*) Observe its legs, the number of parts in the leg, and the number of toes.
(*b*) Compare the leg and toes of a robin with those of a hen.
(*c*) Sketch the claws and leg.
(*d*) Show how they are adapted for grasping and holding.

11. (*a*) Which is the larger bird the male or the female?
(*b*) Describe the difference in appearance of the male and female birds.

D. Its Nest.

12. (*a*) Note the size, shape and material of which the nest is made.
(*b*) Describe the usual situation of the nest.

13. (*a*) Observe the tree preferred by the robin in which to build its nest and note in which part of the tree the nest is placed.
(*b*) Does it build in the woods or near the home of man?
(*c*) Observe whether the old nest is ever used a second time.
(*d*) Observe the bird collecting material for the nest.
(*e*) Note which bird does the work of building.
(*f*) Describe how it uses its bill, claws and breast to fashion the nest.
(*g*) Describe the lining of the nest, and tell where the bird gets it.
(*h*) How long does it generally take to build a nest?

14. While one bird is nest-building what is the occupation of the other?

E. Its Eggs.

15. (*a*) Observe the number, color and size of the eggs.
(*b*) Draw an egg and model one in clay.
(*c*) Infer the advantage of the color of the eggs.

16. (*a*) Describe the actions of the birds when their eggs are being disturbed by boys, bluebirds, blackbirds or crows.
(*b*) Imitate their cry at this time.

17. (*a*) Which bird sits on the eggs until they are hatched?
(*b*) What makes the bird so inconspicuous when on the nest?
(*c*) How long does it require to hatch the eggs?
(*d*) Describe the conduct of the other bird when its mate is on the nest, and when the latter leaves it for food.

F. Its Young.

18. When the young are hatched out, what becomes of the egg-shells?

19. (*a*) Describe how the young are fed.
(*b*) How are they kept warm and protected when it rains?
(*c*) How is the nest kept clean?

20. Describe the young bird—note the covering of the body; the size of the mouth and the appearance of the eyes.

21. On what are the young ones fed?

22. How long is it before the young attempt to leave the nest?

23. Describe their appearance on leaving the nest.

24. Describe the attempts of the old birds to teach their young ones to fly.

25. After the young leave the nest do they ever return to it?

26. How long do the parent birds continue to care for them?

27. How many broods of young are raised in a season?

G. Their Migration.

28. Register the date when they leave for the south and compare it with the time other birds leave.

29. Which of the robins goes first, the male or the female?

The robin likes to be near man. It usually builds its nest near a house. It is to this characteristic that it owes its name. When the first English settlers on this continent saw this friendly bird with a breast colored somewhat like the favorite of their far-away home, they gave it the name robin, though the two birds are really quite unlike except a general resemblance in color.

XIII.—THE SNAKE.

Snakes are beautiful, graceful animals. Most of the North American species are harmless; indeed, all except the rattlesnakes, massasaugas, copperheads and harlequins are so. There is no authentic report of any other venomous snake in Ontario than the rattlesnake. Garter-snakes, green-snakes, water-snakes, racers, milk-snakes and blowing-adders have no poison fangs, and living as they do largely on insects and field mice, they are generally useful to the agriculturist and should be protected. That they sometimes eat the gardener's friends, the toads and young birds, are almost the only charges that can be laid against them.

Confine a garter or other harmless snake in a box having a wire-net lid. A box with such a lid and without a bottom, resting on a separate board for a bottom, is best. In such a box it is easily kept clean. The snake will appreciate a handful of fresh grass or leaves now and again.

A. Its Food and Eating.

1. (*a*) Discover what kind of food it will take.

(*b*) Try insects, earthworms, bits of meat, milk, etc.

(*c*) Infer whether the snake is useful to the farmer.

2. Discover whether it will touch food that does not move.

If it refuses all food offered, a bit of fresh, lean meat may be pushed down its neck with a small, smooth stick.

3. Observe its method of moving its lower jaw when it is taking an earthworm.

4. Have you ever observed a snake taking a frog?

At first the snake will be timid and will not eat when observed, but it soon becomes tame. Different species of snake prefer different kinds of food and vary in the method of capturing it.

B. Its Mouth.

5. Using a small stick or lead pencil discover how the snake can swallow an object of greater diameter than its own head.

C. Its Teeth and Tongue.

6. (*a*) Observe the teeth, their form, number, position and the direction in which they point.

(*b*) Infer why it is difficult for an animal which the snake has seized to escape.

It is easy to feel the teeth with a small stick or pencil.

7. Observe its beautiful forked tongue and try to discover its use.

D. Its Eyes.

8. Touch its eye and discover whether it has eyelids.

E. Its Nostrils.

9. Observe its nostrils and note its breathing.

F. Its Ears.

10. (*a*) Discover whether it can hear.
(*b*) Has its ears external openings?

G. Its Skin.

11. (*a*) Describe the covering of the snake
(*b*) Count the rows of scales.
(*c*) Note whether the scales are flat or ridged.
(*d*) Beginning at the middle row on the back give each row a number—one, two, three, etc., and tell its color.

12. Compare the scales on the under side of the body with those on the upper side in respect to size, shape and color, and infer why there should be such difference.

13. Compare the scales on the head with those on the back.

14. Make a drawing of the head.

H. Its Movements.

15. Use a pane of glass for the floor of the box, and observe how the snake moves itself.

I. Its Casting its Skin.

16. (*a*) Give it food and water and keep it in confinement until it sheds its skin. Its sluggishness and dull eye will warn observers of the time.
(*b*) Observe how the skin comes off.

This may occupy several minutes only, but more likely several hours.

If a descriptive text-book is at hand Fifth-form pupils will be interested in counting the gasterosteges, urosteges and rows of scales and noting the characters of the cephalic plates, in order to identify the species.

17. Illustrate the record of your observations with drawings wherever you can.

XIV.—THE FROG.

A shaded corner of the school-yard may be provided with a shallow water-tight box or a tin dish, sunk to the level of the surrounding ground, a few stones and some loose pieces of sod. This will serve as a temporary home for a few frogs while you are studying their characteristics. When possible observe frogs in the neighborhood of ponds, pools and ditches. A frog may be conveniently kept in a two-quart gem-jar with a wire top. A half-cup of water, frequently changed, should be kept in the jar.

A. Its Food.

1. (*a*) Discover the kind of food relished by the frog.
   (*b*) Try worms, grubs, flies, bread, meat, etc.

A bit of fresh, lean meat may be pushed down its throat if one cannot get living flies, etc.

2. Observe how it uses its tongue.

B. Its Movements.

3. (*a*) Notice how the frog sits when at rest.
   (*b*) Draw it in this position.
4. (*a*) When on land how does it move from place to place?
   (*b*) What particular feature of its structure fits it for this kind of movement?
5. (*a*) Observe a frog swimming.
   (*b*) Draw one in the act of swimming, when the hind legs are fully extended.
   (*c*) Note the peculiarities of structure that fit the frog for swimming.

C. Its Breathing.

6. (*a*) While the frog is at rest, observe its throat, nostrils and the sides of its body.
   (*b*) What process is indicated by these actions?

D. Its Home.

7. Discover where frogs are commonly found.

8. Observe a frog and note whether it spends the greater part of its time on land or in the water.

Animals that spend part of their existence in water and part on land are called *amphibians.*

9. Try to find out what becomes of frogs on the approach of cold weather.

10. What do they eat at this time?

Animals which pass the winter in a torpid state are said *to hibernate.*

E. Its Language.

11. (*a*) Imitate the sounds made by frogs.
(*b*) During which time of the year are their sounds most frequently heard?
(*c*) During which time of the day are their sounds most frequently heard?

F. Its Spawn.

12. (*a*) Procure a mass of frogs' eggs from a pond or ditch, and keep them in wide dishes of water to hatch. Change the water every two or three days, taking fresh water from a pond or ditch, not from a well.
(*b*) Describe the mass of eggs.
(*c*) Examine a single egg. Describe it. Draw it.
(*d*) What are the first signs of life observed in the eggs?

G. The Tadpole.

13. (*a*) Describe the creature that comes out of the egg when it breaks.
(*b*) How does it swim?
(*c*) Examine closely for gills. Describe any appendages you may find.

14. Examine its mouth to discover whether it has teeth or tongue.

15. Take two glass jars. Fill each with water from a neighboring pond. Place the same kind of water-plants in each, and in one put some tadpoles. After a time, note the difference of the water in the two jars.

16. (*a*) Discover what the tadpole eats. Try insects, worms, bread, small water-plants, etc.

(*b*) Investigate whether mosquitoes are reduced in numbers by tadpoles and whether they eat vegetable matter.

17. (*a*) Describe the changes which gradually take place in the tadpole as it develops.

(*b*) Which disappear first the tail or the gills?

(*c*) What becomes of the tail?

(*d*) Which develop first the fore or the hind legs?

The passing of an animal from one form or shape to another is called its *metamorphosis.*

18. Draw tadpoles illustrating various stages in their development.

19. (*a*) Place one of the tadpoles on a piece of glass with a little water, and examine the gills or a thin part of the tail with a microscope. The flow of the blood can be readily seen.

(*b*) Describe the flow of blood.

H. Circulation of the Blood.

20. (*a*) Procure a thin piece of board as a shingle, cut a V-shaped notch in one end, or bore a hole through it near the end and gum a thin, clear plate of mica over the hole. Wrap a frog in a wet cloth, with a leg projecting, and tie it to the board with a part of the

web stretched not too tightly over the V-shaped notch or hole. Examine with a microscope using the objective of low power. Arteries, veins and capillaries will be plainly visible. With a higher power the corpuscles can also be distinctly seen.

(*b*) How can you distinguish veins from arteries?

(*c*) What is the nature of the capillaries?

(*d*) Draw the arteries, capillaries and veins and a corpuscle.

(*e*) Are the corpuscles all of the same form and color?

(*f*) Why do the corpuscles seem so much paler than the blood when seen with the naked eye?

(*g*) If you have a compound microscope compare as to size, shape and markings, the red blood-cells (corpuscles) of a frog with those in the blood obtained by pricking your finger.

I. Its Structure.

THE HEAD.

(1) *The Mouth.*

21. (*a*) Observe the form and size of the mouth.

(*b*) With the fingers or a small, smooth stick open it and note the shape of the upper and lower jaws.

(2) *The Teeth.*

22. (*a*) Examine the teeth. Draw the fingers over them.

(*b*) Where are they situated?

(*c*) After observing the way in which the frog swallows its food, infer the use of teeth to the frog.

(*d*) Compare as to size, number and position, the teeth of a frog with those of the cat, snake and fish.

(3) *The Tongue.*

23. (*a*) Discover where the tongue is attached in the mouth.

(*b*) Where does the end lie?

(*c*) Infer the purpose of this arrangement of the tongue.

(*d*) Infer the use of the sticky fluid covering the tongue.

24. Draw the open mouth of the frog, showing the tongue and the teeth.

25. If you have seen the frog catching an insect, draw the tongue in the act.

(4) *The Eyes.*

26. (*a*) Note their position.

(*b*) Gently touch the eye and note the result.

(*c*) How many eyelids are there? Where are they when not in use?

(*d*) Observe the shape of the pupil.

(*e*) Draw an eye.

(5) *The Nostrils.*

27. Discover them and note their number and position.

(6) *The Ears.*

28. (*a*) Discover whether the frog can hear.

(*b*) Where is the ear-drum placed?

THE LEGS.

29. (*a*) Examine a fore leg.

(*b*) Of how many parts is it composed?

(*c*) How many toes are there?

(*d*) Draw a fore leg.

30. (*a*) Examine a hind leg; note the parts of which it is composed; the number of toes and how they are connected.

31. Contrast a fore and a hind leg; also a fore and hind foot.

32. Draw a hind leg.

THE SKIN.

33. Observe the general shape and appearance of the frog.

34. Where is the neck of the frog?

35. (*a*) Note the color of the upper surface of the head and back.

(*b*) Compare the color of the upper and under surfaces of the body.

(*c*) If possible, discover whether the frog can change the color of its body.

(*d*) Infer the purpose of the color and color-markings.

36. Discover whether the skin is sensitive or not.

37. Compare the frog with the toad in respect to form, food and habits.

38. Of what use is the frog?

XV.—THE FISH.

In addition to observing fish in a neighboring stream, place a number of minnows or other small fish in an aquarium. A tub partly filled with water will answer very well. Two or three minnows may be kept some time in a glass gem-jar. The water should be changed every day.

A. Its General Appearance.

1. Notice the shape of the fish.
2. Point out the *head*, the *body*, the *tail.*
3. Draw a fish.

B. Its Movements.

4. (*a*) Observe the movements of the fish, and discover how it makes them.
   (*b*) Describe its movements.
5. Point out how the shape of the head and body facilitate rapid motion through the water.

C. Its Food.

6. (*a*) Offer different kinds of food to the fish, such as insects, worms, crumbs, etc.
   (*b*) Discover which kind it likes best.
7. Describe how it eats.

Fish are generally timid and not very intelligent. However, in time they learn to know those who feed them.

D. The Head.

(1) *The Mouth.*

8. Examine the mouth; note its shape when closed and when open.
9. Discover whether the fish has teeth; where they are situated; how they are inclined, and infer their use to the fish.
10. (*a*) Discover the tongue; feel its surface with the tip of the finger.
    (*b*) Can it be protruded as in the frog?

(2) *The Eyes.*

11. (*a*) Note the shape and position of the eyes.
(*b*) Discover whether there are eyelids or not.
(*c*) What provision is made for protecting the eye-ball?
(*d*) Discover whether the eye-ball can be turned in various directions.
(*e*) Observe the pupil.
(*f*) Draw an eye.
(*g*) Compare the eye of the fish as to covering with that of the frog or snake.

(3) *The Nostrils.*

12. Discover the nostrils, note their number, exact location and arrangement.

(4) *The Ears.*

13. Discover whether a fish can hear.

(5) *The Gill-Covers.*

14. (*a*) Observe the flaps along the sides of the head
(*b*) Note which edges are free and which are attached.
(*c*) Examine the large openings along the sides of the head. Note their extent.

(6) *The Gills.*

15. (*a*) Raise a gill-cover and observe the red structure beneath it.
(*b*) Of what does a gill consist?
(*c*) How many gills are there?
(*d*) How many gill-clefts are there?

16. (*a*) Observe the movement of the lower jaw and gills.

(*b*) Discover the connection between the rhythmical arching of the gills and the opening of the mouth.

(*c*) Why are these actions connected?

17. Remove a fish from the water for a short time and observe how this affects the fish.

18. (*a*) Fill test-tubes with well water, rain water, creek water, unshaken boiled water, boiled water well shaken or stirred with an egg-beater, and label them. Let them stand side by side several hours and then examine them for air-bubbles.

(*b*) If air is necessary for the respiration of fish, in which of the above kinds of water would a fish live longest?

(*c*) Make a list of the samples of water in the order of their capacity for supporting the respiration of fish.

E. The Body.

19. (*a*) Note the outline of the body as seen from above, from the sides, and from below.

(*b*) Make sketches showing these outlines.

(*c*) Mark the *lateral line.*

20. (*a*) Observe the covering; note the arrangement of the scales; their size; their thickness; their shape and color.

(*b*) Sketch a scale.

(*c*) Infer the advantage to the fish of having the scales arranged as they are.

F. The Appendages.

21. Point out the appendages to the body.

22 (*a*) Point out those nearest the head.

(*b*) How many are there?

(*c*) Compare their position on opposite sides of the body.

The anterior fins are the *pectoral fins.*

(*d*) Sketch the pectoral fin of the fish you are studying.

23. (*a*) Observe another pair of fins situated farther back and more nearly on the under surface.

The posterior pair of fins situated on or near the abdomen of fish are **the** *ventral* or *pelvic fins.*

(*b*) Sketch the ventral fin of the fish you are studying.

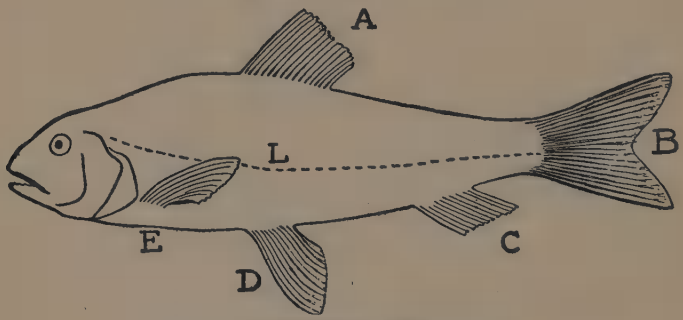


DIAGRAM OF A FISH.

A—Dorsal Fin.
B—Caudal Fin.
C—Anal Fin.
D—Pelvic Fin.
E—Pectoral Fin.
L—Lateral Line.

24. (*a*) Observe the fins extending along the middle of the back.

(*b*) Stretch them out and observe the number of bony structures forming the framework.

The fin along the middle of the back is the *dorsal fin.*

25. (*a*) Examine the fin forming the tail of the fish.

(*b*) Spread it out and note its appearance.

The fin forming the tail of the fish is the *caudal fin.*

(*c*) Draw the caudal fin.

(*d*) Compare the upper and lower halves of this fin.

(*e*) Are they symmetrical or not?

(*f*) What is the special function of this fin?

26. Examine the fin on the middle line of the lower surface of the body, just in front of the caudal fin.

The fin behind the opening into the abdomen is the *anal fin.*

27. (*a*) Point out the fins which grow in the middle line of the body above and below.

(*b*) In what direction do they extend?

(*c*) Do they occur singly or in pairs.

28. (*a*) Point out the fins which grow in pairs.

(*b*) How many such pairs are there?

29. Name parts of the frog, the hen, and man which are homologous to the pectoral fins.

NOTE.—Organs that develop from like parts are said to be homologous; *e.g.*, nails and claws; the wing of a bird is homologous to the arm of a man, but not to the wing of an insect; the third pair of legs of a spider is homologous to the first pair of a fly.

30. The pelvic fins are homologous to what part of the frog? of the hen? of man?

31. Draw a minnow or other fish and mark the name of each fin.

32. By watching the fish in water, discover the special use of the different pairs of fins and of the single ones.

XVI.—THE EARTHWORM.

Bore holes in three sides of a good-sized wooden-box to admit air. Almost fill the box with rich, moist earth mixed with partially-decayed leaves and stems. Plant in this earth some growing fibrous roots. Collect some earthworms; leave them on top of the earth. Put the box in a somewhat shady part of the school-yard. At times moisten the top by way of encouraging worms to come to the surface. By this means some satisfactory observations on earthworms can be conveniently made. Earthworms, however, are seen to best advantage in their native home, after a warm rain in early morning or on a dull day. Do not fail to see them when opportunities for such observations occur.

A. Its Movements.

1. (*a*) Dip a worm into water to moisten its body and then place it on a sheet of paper. Watch its motions.

(*b*) How does it crawl?

(*c*) Does it move with the same end always foremost?

(*d*) Gently touch one end with a pencil and note the result.

(*e*) Touch the other end and infer which is the more sensitive.

2. Discover how it is enabled to climb a smooth vertical surface.

B. Its Food.

3. (*a*) Discover the kind of food on which the worm lives. Try raw meat, cooked meat, onions, cabbage, leaves of plants. Bury portions of these in the box and examine sometime later.

(*b*) Infer a use of the worm to man.

C. Its Home.

4. Put two or three worms in a glass of damp earth and observe how they bore their way through the ground.

5. (*a*) Observe and examine worm-casts.
   (*b*) Note how they are heaped, the shape and general appearance of each.
   (*c*) Discover where these casts come from and how the worm brings them to the surface.
6. (*a*) Keep a worm out of the ground for a time and then compare it with one just taken out.
   (*b*) What difference is observed?
   (*c*) Infer the reason for this.
7. (*a*) With a trowel remove layer after layer of earth and expose several worm-holes, being careful to examine the holes as they descend.
   (*b*) Note what is found in the holes.
   (*c*) Infer the use of these to the worm and to man.
8. (*a*) Describe the home of the worm.
   (*b*) Note its rows of halls and how the walls are prevented from falling in.
   (*c*) Draw a plan of the home of the worm.
9. (*a*) Place a few worms in a small water-tight box partly filled with earth, and after they have burrowed a home for themselves pour a little water into the box.
   (*b*) Observe the actions of the worms.
   (*c*) Infer why there are so many worms to be seen just after a rainstorm.
10. Observe whether worms live alone or are social.
11. Collect the worm-casts for a few days from the same square yard of earth. Weigh them and then estimate how much would be brought to the surface during one day on an acre.
12. Discover whether worms bring up as much earth during the daytime as they do at night.

13. (*a*) Infer the effect of their work upon the soil.
(*b*) What service is this to the gardener and farmer?

14. Examine the roots of the plants in the box and note whether worms are injurious to them by eating their roots.

15. In what kind of soil are worms most abundant?

16. If possible, discover what becomes of worms in very dry weather; also in winter.

D. Its Senses.

17. Touch a worm gently and decide whether it has feeling or not.

18. Present substances of various odors and decide whether the worm can smell.

19. Place the worm in a strong light and then darken the room and decide whether the worm can distinguish between light and darkness.

20. Experiment so as to decide whether it can see objects or not.

E. The General Appearance and Structure.

21. (*a*) Take a fresh earthworm and examine and compare the two ends of the body.
(*b*) Which do you think is the forward end and which the hinder end? Why?
(*c*) How do the two ends differ?

22. (*a*) Place a worm upon paper and observe its movements.
(*b*) Turn it over and note what happens.
(*c*) Which is the lower surface of the worm?
(*d*) Which is the upper surface of the animal?
(*e*) In what respects do they differ?

23. (*a*) Of what is the body of the earthworm composed?

(*b*) Are these segments everywhere exactly alike?

4. (*a*) Note a thick band a little back of the anterior end of the body.

(*b*) Describe this band.

(*c*) Over how many segments does it extend?

25. How many segments are in front of the band?

26. Examine the surface of the body by laying the worm over the tip of the forefinger and dragging it backward and forward.

27. (*a*) Seize a worm near the posterior end with a pair of forceps and draw it backward.

(*b*) Is there resistance?

(*c*) With a lens discover small bristle-like structures in the body-wall. Make a drawing of one as seen under a compound microscope.

(*d*) Where are they situated and how are they arranged?

(*e*) In what direction do they point?

The small bristle-like structure is called a *seta* (plural *setæ*).

(*f*) Of what use are these to the worm in crawling?

28. Why is it difficult for a robin to drag an earthworm from its hole in the ground?

29. Draw an earthworm.

F. The Young Worm.

30. (*a*) Where are the eggs deposited?

(*b*) Describe the bag which contains them.

XVII.—THE BEE.

In order to get the full benefit from studying the bee, one or more bee-hives must be visited. A hive may be constructed so that the operations of the bees can be readily observed. Some apiarist in the neighborhood might, on request, bring such a hive to the schools to let the pupils observe and study it under his direction.

A. The Bee Among Flowers.

1. (*a*) Discover what it is doing.
   (*b*) Does it rest on the flowers?
   (*c*) Note the kind and the color of the flowers visited, and the order in which they are visited.
   (*d*) Make a list of flowers visited by bees.
2. (*a*) Imitate the sound made by the bee.
   (*b*) When does the bee make this sound?
   (*c*) Compare it with the sounds made by the fly and the grasshopper.
   (*d*) Discover how the sound is produced in each case.
3. (*a*) Describe the action of the bee as it approaches different flowers.
   (*b*) With what is its body frequently covered?
   (*c*) Infer the use of the bee to the flower.
   (*d*) Does the bee make any use of this powder for itself?
   (*e*) Does it lose any of that gathered?
   (*f*) Observe the bee as it moves from flower to flower.
4. Observe bees at home and notice their actions.
5. (*a*) Examine the leg of a bee.
   (*b*) Describe and draw it.
   (*c*) Compare it with the leg of a fly, grasshopper or butterfly.
   (*d*) Tell the use the bee makes of each part of its leg.

The bunch of hairs on the legs of the bee is called the *brush.*

The flattened, hairy outer surface of the hind upper part of the leg of a bee is the *basket.*

6. Taste the lower ends of different petals, especially of the flowers frequented by the bee, to determine what else the bee obtains from the flower besides pollen.

7. (*a*) What does the bee do with the honey it gathers?
   (*b*) Watch it as it goes to and from the hive.
   (*c*) Infer the reason for its activity, and discover how it carries the honey.

8. (*a*) Observe the bee on a flower too small for it to enter.
   (*b*) Infer from its actions how it uses its tongue.
   (*c*) With a lens observe the little scales between the segments of the abdomen.
   (*d*) If possible, observe how it plucks out these scales.
   (*e*) What use does it make of them?

9. Where does the bee get wax?

10. (*a*) Observe whether the bee ever visits the blossoms of fruit-trees.
    (*b*) At what time of the day do we find the greatest number of bees at work among flowers?
    (*c*) Infer the reason of this.

11. Draw the different parts of its body.

12. Draw the bee on a flower.

13. Model the bee in clay.

The fore part of the bee is the *head;* the middle part is the *thorax;* and the hind part is the *abdomen.*

14. (*a*) On which subdivision of the bee are the legs placed?
    (*b*) How many pairs of legs has the bee?

15. (*a*) On which subdivision are the wings placed?
(*b*) How many pairs of wings are there?

B. The Bee at Home.

16. (*a*) If possible, have a glass plate put in one side of a hive.
(*b*) Observe any difference in the size of the bees; in the shape of their bodies; in their legs.
(*c*) Infer the reason for this difference.

The largest bee is the *Queen*. She has a slender abdomen.
The small bees are the *workers*.
Those intermediate in size are the *drones*.

(*d*) Discover which of these kinds of bees have stings.

17. Draw a bee of each kind and discover the particular kind of work it has to do.

18. (*a*) Observe the comparative number of each kind of bees in a hive.
(*b*) Infer the advantage of having different kinds of bees in a hive.

19. In the autumn how are the drones treated by the other bees in the hive?

20. (*a*) Observe the **working-bee** building the cells.
(*b*) Describe how it lays the sheets of wax; how it gets the wax off its body; the shape of the cells; how the single partition serves for the double boxes and infer from this the skill of the bee and its intelligence in economizing time and labor.
(*c*) Draw several of these cells side by side.
(*d*) Model several of these cells side by side in clay.

This collection of cells is called the *honey-comb*.

21. What advantage is to be gained for the bee by providing it with honeycomb?

22. (*a*) Observe the different uses the bee makes of these cells.

(*b*) Of what use to the bee is the honey and pollen stored in the cells?

The nectar and pollen stored in the cells to be eaten by the bees is called *bee-bread.*

23. (*a*) Observe the work of the mother or queen-bee.

(*b*) Describe an egg.

(*c*) Note the way in which the working-bees treat the mother-bee.

(*d*) Describe the appearance of the cells after the eggs have been deposited.

(*e*) Discover into what the eggs hatch.

The small grub-like creature which comes from the egg is a *larva* (plural *larvæ*).

24. (*a*) Examine several larvæ.

(*b*) Infer the reason for the difference in the appearance.

(*c*) Describe the treatment given to the different kinds of larvæ.

Young bees less than sixteen days old are called *nurse-bees.* After this they become *field-bees.*

25. Observe the change that takes place in the larvæ.

When the larva ceases to feed and spins a covering, called a *cocoon,* it becomes a *pupa* and the insect is said to be in the *pupal stage* of development.

26. (*a*) Observe what comes from a *cocoon.*

(*b*) How long is it from the time the cocoon is formed before the bee appears?

27. Through what transformations does the egg pass before the perfect bee appears?

The perfect insect is called the *imago.*

28. (*a*) Describe the young bee as it comes out of the cell.

(*b*) How do the working-bees treat it?

(*c*) Where does it get its food at first?

29. (*a*) Describe the way in which the queen-bee treats the "young queen," and how this new queen is protected.

(*b*) If the young queen dies how do the bees act?

C. The Enemies of Bees.

30. (*a*) Observe the way in which bees treat such foreigners as caterpillars, moths, flies and slugs.

(*b*) Observe whether bees have any other enemies than those mentioned in (*a*). If so, what are they?

D. Bees Leaving the Old Home.

31. (*a*) Describe the actions of the mother-queen when she hears the first song of the young queen; observe her attempts to use her sting in order to kill this queen.

(*b*) Note how she is defeated by the workers.

(*c*) Observe her flight from home followed by a number of bees; their appearance as they hang together in a bunch on a vine, or branch.

32. Observe how the bee-owner treats these bees and note how actively they proceed to build a new home.

E. The Disturbed State of the Old Home.

33. Describe:

(*a*) The actions of the workers to the new queen.

(*b*) The battle between the new queens should more than one appear.

(*c*) The action of the working-bees towards the fallen queens.

(*d*) Their loyalty to the new queen.

F. Bee-Keeping.

34. Describe:

(*a*) How bees are hived.

(*b*) How honey is removed from the hive.

35. (*a*) Observe how the liquid honey is extracted from the comb.

(*b*) What is the average quantity extracted from each hive?

36. How are bees cared for in winter?

37. What uses have you seen made of honey? Of beeswax?

38. Inquire of bee-keepers to learn what you can about the storing and marketing of honey, the importation and sale of hives and queens, and the profitableness of bee-keeping.

XVIII.—THE POTATO-BEETLE.

Into a box—an empty chalk-box will do—put an inch or two of soil. Collect leaves with clusters of eggs; place them in the box; cover the top with a pane of glass. When the eggs hatch feed the larvæ with fresh leaves as often as necessary. If possible, study the beetle in the potato-patch.

A. The Egg.

1. On which side of the leaf are the eggs found?

2. Describe the cluster; also a single egg.

3. Into what do the eggs develop?

4. How long is it from the time the eggs are laid until they hatch out?

B. The Larvæ.

5. Describe the larva.

6. How does the larva eat?

7. How long does the larval state continue?

8. When the larvæ are transformed what becomes of them?

The larvæ of beetles are frequently called *grubs* or *borers*.

C. The Pupa.

9. Describe the pupa.

10. How long does it continue in the pupal stage?

11. In what respects does the young beetle resemble the full-grown one?

12. How long is it before it becomes a fully-developed potato-beetle?

13. Contrast the manner of eating of the fully-developed beetle with that of the larva.

D. The Beetle.

14. Describe the beetle, its covering, its color and markings.

15. Point out the different parts of its body and describe the shape of each.

16. (*a*) How many legs has it?
(*b*) On which part of the body are they situated?

17. (*a*) Describe the head, eyes and jaws.
(*b*) Compare its eyes with those of the grasshopper and the housefly.

18. Draw the head and eyes.

19. Describe the legs and feet.

20. Observe the movements of the beetle and show how the legs are adapted to its walking movements.

21. Contrast its legs with those of the grasshopper.

22. (*a*) Raise the hard wings of the body and discover the membranous wings.

(*b*) To what part of the beetle are these wings attached?

(*c*) Describe each pair of wings.

23. (*a*) Observe how the beetle flies.

(*b*) Infer the use of the hard wings.

24. Describe the under parts of the body.

25. Discover how the insect breathes.

26. Draw a fully-grown beetle in various positions.

27. Discover where the potato-beetle passes the winter.

28. (*a*) Examine the mouth of a beetle.

(*b*) Infer how it eats.

(*c*) Compare its mouth with that of the butterfly and bee.

29. (*a*) From your studies of Nos. 4, 7, 10, and 12 estimate how many broods there are during the potato season.

(*b*) Count the eggs in a cluster and estimate how many beetles may be produced in the season from one cluster of eggs laid on an early potato-shoot.

(*c*) To what different means have you seen potato-growers resort to destroy the beetles?

30. (*a*) Discover other kinds of beetles.

(*b*) Note the different habits of each kind.

(*c*) Make notes and drawings of each kind.

XIX.—THE CABBAGE-BUTTERFLY.

The study of this insect may begin with the egg of the butterfly, the larva, the pupa, or with the butterfly itself.

Butterflies may be caught and put into an empty hat-box or small barrel with one end knocked out. Put in some cabbage-leaves or leaves of any of the cruciferous family. The butterfly will deposit its eggs on these leaves if fresh. Put also some chips and twigs in the box. Cover the box with cheese-cloth or fly-netting. As soon as the grub appears renew the leaves. Put in fresh leaves from day to day.

In due time the pupal stage will be reached, the insect will attach itself to a twig or side of the box, and pupate in the form called a chrysalis. If kept in a cool place the butterfly will appear. Watch the different changes closely from day to day.

A. The Egg.

1. (*a*) Make observations in a cabbage-patch; also observe the insects as preserved in the box.
   (*b*) Why do so many butterflies visit the cabbage-patch?

2. On which side of the leaf does the butterfly deposit its eggs?

3. (*a*) Why are the eggs so difficult to find?
   (*b*) Infer the advantage of their concealment to the butterfly.

4. Why do the eggs not fall off the leaves?

5. Are the eggs in clusters, or are they scattered here and there?

6. Does this butterfly deposit its eggs on any other kind of plant than the cabbage-plant?

Examine the leaves of radish, turnip, mignonette, and other vegetables.

7. (*a*) Make a drawing of one of the eggs. (Use the lens.)
   (*b*) Has it a shell?
   (*c*) What color is it?
   (*d*) Is its color any protection to it?

8. Discover other things in Nature that are protected by their color.

9. Draw a leaf showing the egg or eggs attached to it.

B. The Larva.

10. (*a*) How did the larva get out of the egg?

(*b*) Describe this larva. Draw it.

The larvæ of butterflies and moths are sometimes called *caterpillars* and sometimes *worms*.

11. (*a*) Describe the appearance of a leaf on which you have found a larva.

(*b*) Do they eat the leaf-tissue or do they suck the sap from it?

12. Describe the way in which this larva eats.

13. Examine the leaves infested by other larvæ and determine whether they eat in the same manner as this one.

14. Describe the way the lárva crawls.

15. Into how many parts is its body divided?

The teacher will show you what is meant by a *segment* of a larva.

16. How many legs has this larva?

On the posterior segments of this larva, and of other but not all kinds of larvæ, there are pairs of appendages resembling legs which are called *prolegs*.

17. Compare these prolegs with the true legs on the segments near the head in respect to number, size, shape, joints, color, and use.

18. How many segments are without legs of any kind?

19. (*a*) Dust some insect powder on the larvæ; watch the result.

(*b*) What has caused the death of the larvæ?

(*c*) Would sprinkling the powder on a cat or a dog be likely to cause death? Why not?

20. (*a*) Observe the small openings which may be seen in large cabbage-larvæ along each side of the abdomen, in the same line as the yellowish dots. These openings are the ends of tubes that supply air.

(*b*) If these breathing-holes become clogged what will happen to the larva?

(*c*) Describe the way in which the larva breathes.

21. How may gardeners prevent the destruction of their cabbage-plants by these larvæ?

22. (*a*) Observe the sloughs in the box where the larvæ are confined. What are these?

(*b*) Why does the larva cast its skin?

When the larva casts off its outside covering it is said *to molt*.

(*c*) Try to find how many times each larva molts.

C. The Pupa, Sometimes Called the Chrysalis.

23. Describe the change in the form of the larva.

24. (*a*) Observe the larva in the breeding-box from day to day, and note the pupating among the leaves.

(*b*) Describe the larva in its new form.

The inactive form of an insect usually enclosed in a case and from which the perfect insect emerges is called a *chrysalis* or *pupa*.

25. (*a*) How long is this chrysalis?

(*b*) How is this chrysalis suspended?

(*c*) Where did the larva get the thread by which it attached itself to the twig?

(*d*) What is the color of the chrysalis?

26. Examine a case to discover whether it is thick or thin.

27. Draw the pupa-case.

28. Open a pupa-case.

29. Observe closely to see whether the chrysalis changes its form.

30. Make records with a view to discover how many days the insect remains in the pupal condition.

31. Examine the empty case.

32. Describe the butterfly immediately after its emergence from the chrysalis stage.

33. What are the different stages through which it has passed?

34. Draw the butterfly in different positions.

35. (*a*) Into how many parts is the body of this new form divided?

(*b*) How many wings has it?

(*c*) How many legs has it?

(*d*) How many antennæ?

(*e*) How many eyes?

36. After study of the butterfly show why it is a true insect, and compare it with some other kind of insect, as the bee or grasshopper or potato-beetle.

D. The Butterfly and its Parts.

Try to obtain a few specimens; kill them by placing them in a poisoning-jar. Such jars are made by placing in them cotton-batting saturated with chloroform or carbon bisulphide, or putting in one or more lumps of cyanide of potassium. The last-mentioned poison is frequently embedded in plaster of Paris in the bottom of the jar. Pin them on cork in order to be able to make closer observations. Also collect specimens for the breeding-cage. While the eggs are developing, study the butterfly as a whole.

37. (*a*) Observe the butterfly among the flowers.

(*b*) What were the butterflies doing among the flowers?

(*c*) Make a list of plants upon which you have seen these white butterflies resting.

(*d*) What part of the flower does it use for food?

38. How does it get the nectar out of the flower?

(1) *The Tongue.*

39. Examine the pinned insect. Do you see any part of the head that might help the insect to get the nectar?

Put a straw in a bottle containing water and suck some of it up.

40. (*a*) Describe the tongue.

(*b*) Put a drop of thin syrup made of sugar and water on a leaf and observe how the butterfly uses its tongue.

(2) *The Antennæ.*

41. Describe the antennæ.

A butterfly is distinguished from a moth by the *antennæ* (singular *antenna*). The antennæ of moths are without knobs or thickenings at the outer ends.

42. Of what use are the antennæ to the butterfly?

All the uses of the antennæ are not known. The senses of touch, hearing and smell may reside in them. If they are cut off the insect does not fly.

(3) *The Eyes.*

43. (*a*) Where are the eyes of the butterfly situated?

(*b*) Compared with the size of the insect are they large or small?

(*c*) How many eyes has the butterfly?

44. Draw the head of a butterfly, and mark the position of the eyes.

(4) *The Legs.*

45. (*a*) How many legs has the butterfly?

(*b*) Examine other butterflies to discover if they have the same number of legs as the cabbage-butterfly.

(*c*) How are the legs placed?

(*d*) Does a butterfly use its legs in the same way as a fly?

46. (*a*) Into how many parts is each leg divided?
(*b*) Draw a leg.

47. Draw the body of the butterfly, and show the position of the legs.

(5) *The Wings.*

48. (*a*) How many wings has the butterfly?
(*b*) How are these wings placed?
(*c*) How is the position of the wings related to the position of the legs?
(*d*) Are they all the same size?

49. (*a*) Describe the appearance of the wing after it has been rubbed.
(*b*) What has come off the wing?

The powder is really little scales.

50. (*a*) What effect is produced upon the color of the wings by rubbing them?
(*b*) To what is the velvet-like appearance of the wings due?

51. In what way do these wings differ from those of a fly?

52. (*a*) How does a butterfly hold its wings when it is resting on a flower?
(*b*) Draw it in this position.
(*c*) Compare the ways in which butterflies, beetles, and birds use their wings.

E. The Haunts.

53. (*a*) Do butterflies frequent other parts of plants than the flowers?
(*b*) What were they doing in the vegetable-garden?

F. Cocoons.

54. Capture larvæ; put them in a breeding-cage and feed them with the leaves of the plant on which they were found until they pupate, or spin up into cocoons.

The envelope spun by the larva and in which it is enclosed in the chrysalis state is a *cocoon*.

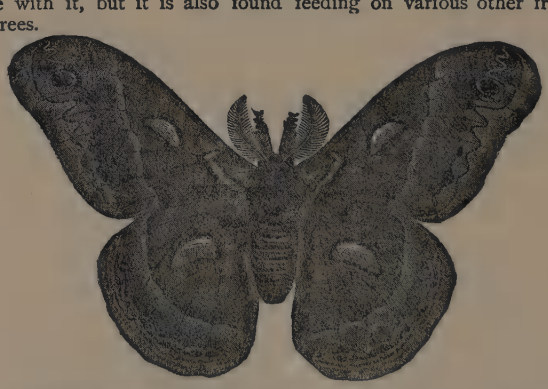
55. Keep the cocoons and observe them until the transformations are completed, then dissect the empty case.

G. The Breeding-Cage.

Procure an ordinary store-box, a hat-box answers very well. Provide a lid made from a frame large enough to fit the box, and stretch gauze over the opening in the frame. Set jars or bottles with the food-plant in the box, stuffing something around the neck of the jar to prevent the larvæ accidentally falling into the water.

XX.—THE CECROPIA EMPEROR MOTH.

The larva of this moth is a general feeder. The apple-tree is a favorite with it, but it is also found feeding on various other fruit and shade trees.



1. Collect a number of larvæ, place them in the breeding-cage and feed them until they spin an envelope in which they are enclosed.

The envelopes spun by larvæ and in which they enclose themselves are called *cocoons*.

2. (*a*) Describe the cocoon, its shade, color, length and breadth.

(*b*) Note how it is attached to the twig.

3. (*a*) Examine an empty cocoon.

(*b*) Describe the outer wall.

(*c*) Remove this and describe what is underneath.

(*d*) Remove the second covering and describe the inner cocoon.

4. What are the advantages of such an arrangement of the coverings?

5. Compare the way in which the fibres are woven at the small and large ends.

6. (*a*) Open a tenanted cocoon.

(*b*) Describe what it contains.

The inactive form of this as well as of many other insects enclosed in a cocoon and from which the perfect insect emerges is a *chrysalis*.

7. (*a*) Watch a moth escaping from the cocoon and describe what is taking place.

(*b*) At which end of the cocoon does it escape?

8. How are the fibres softened to allow the moth to pull the threads aside?

9. What advantage to the insect is it to have the fibres of one end more loosely woven than at the other end?

10. (*a*) Which part of the moth is first protruded?
(*b*) Describe how little by little the entire insect escapes from the cocoon.

11. Describe the insect in its first appearance.

12. Describe it after its wings are dry.

13. (*a*) Compare this moth with the cabbage-butterfly in respect to form of antennæ and time of day in which each prefers to be on the wing.
(*b*) Infer a general distinction between a moth and a butterfly.

14. (*a*) Collect the larvæ of other insects and treat them in a similar way to those of the cecropia emperor moth. Those of the promethea may be collected on the wild cherry-tree and those of the polyphemus on plum-trees, the woodbine, grapevines and lilac-bushes.
(*b*) Observe how the cocoons are fixed on the leaf and, in the case of the former, how the leaf is fixed to the branch.

XXI.—THE GRASSHOPPER.

Few, if any, insects are better adapted for the study of insect-structure than the grasshopper.

Besides making observations in the garden and in the field confine a few grasshoppers in a wire cage improvised for the purpose. Make four frames with light slats; cover these with fly-netting, tack them together and cover the top with the netting. Then take a shallow box containing a few inches of earth. In it plant both long and short grasses. Over this box, set the frame. Such a cage will allow free circulation of air which is absolutely necessary to the life of the grasshopper.

A. General Description.

1. Describe the grasshopper, the shape of the body, the number of its parts, how the head is set on the body, the collar, the number of legs and wings—their position on the body.

The part of an insect to which the head is attached is the *thorax*. The hind section is the *abdomen*.

2. Observe the rings on the body. Count them and infer their use.

B. Its Movements.

3. (*a*) Observe the grasshopper *jumping*.
   (*b*) Discover the part of the body that gives it such power of movement.

C. Its Legs.

4. (*a*) Describe the legs, their position and parts.
   (*b*) Compare the hind legs with the front legs with regard to size, shape and strength.

5. Discover:
   (*a*) How the hind legs are fitted for jumping.
   (*b*) How the front legs are fitted for holding and climbing.

6. Draw:
   (*a*) The hind legs.
   (*b*) The front legs.

7. Describe the feet.

D. Its Head.

8. (*a*) Describe the head.
   (*b*) Infer why it is so hard.
   (*c*) Infer also why the eyes are so large.
   (*d*) Discover the use of the antennæ.

E. Its Mouth.

9. (*a*) Describe the mouth.
   (*b*) Observe how it moves its jaws and its upper-lip.
   (*c*) Discover the advantage of these movements.

F. Its Neck.

10. (*a*) Examine the neck.
(*b*) Infer why it is so soft and flexible.
(*c*) Discover the use of the collar.

G. Its Wings.

11. (*a*) Discover why the outer pair of wings are so tough while the inner pair are so delicate.
(*b*) Describe the wings and show how they are fitted to the life of the grasshopper.
(*c*) Compare them with the wings of a butterfly.

12. Draw a grasshopper:
(*a*) With folded wings.
(*b*) With wings spread out for flying.

13. Compare its wings with those of a cricket and with those of a fly.

H. Its Respiration.

14. What evidences have you that the grasshopper breathes?

15. Describe the expansion and contraction of the body.

16. (*a*) Using a lens observe the openings along the abdomen and thorax in a row on the side.
(*b*) How many of these openings are there?
(*c*) Show them in the drawings you have made.
(*d*) Infer how insects are readily killed by covering them with varnish.

17. Using the microscope observe the opening on the first abdominal segment.

The opening is supposed to be the organ of hearing.

I. The Eggs.

18. Observe the projections on some grasshoppers from the last segment of the abdomen.

The projection at the extremity of the abdomen of the female is the *ovipositor*. Through this the eggs are deposited.

(*a*) Discover, if you can, the holes in the ground—the nests—made by the grasshopper in which to deposit her eggs.

(*b*) Make a drawing of a nest and of an egg.

J. Observations for Advanced Class.

19. Discover to what extent the structure of the grasshopper agrees with that of the bee, the house-fly and the cricket, and to what extent it differs.

20. (*a*) Immerse a partially-anæsthetized form in alcohol and observe that small bubbles of air are expelled. The contraction of the body will force bubbles of air, which can readily be seen from the openings on the abdomen and thorax.

(*b*) Remove a part of the body near these openings; with needles take out and examine under a microscope the spirally-wound trachea.

21. (*a*) Remove the crystalline covering of the compound-eye and examine part of it under a microscope.

(*b*) Make drawings representing the appearance.

Each of the hexagonal spaces represents a single eye.

I. First Stage—1, 2, 3, 4, eggs; enlarged in 3 and 4.

II. Second Stage—5, 6, 7, larva—caterpillar, grub, maggot, worm, borer; ▮ (*a*) spiracle; (*b*) true legs; (*c*) prolegs.

III. Third Stage—8, 9, 10, pupa, cocoon, chrysalis.

IV. Fourth Stage—11, 12, 13, imago—butterfly, moth, bee, fly, beetle; (*a*) antenna; (*b*) thorax; (*c*) abdomen.

These figures are not different stages of three different insects, but one or more stages in the life-history of eleven different insects.

XXII.—CLOVER.

1. Collect and bring to the class a plant of each of the different kinds of clover that you can find.

Why is it better for each pupil to collect his own specimens than that another pupil or the teacher should collect the supply for the class?

2. How can you distinguish a clover from other kinds of plants? In answering this question refer to:

(*a*) The arrangement and number of the leaflets.

(*b*) The position or arrangement of the flowers.

(*c*) The structure of the flower.

(*d*) The shape of the seed-pod.

White clover, red clover and Alsike clover are common; in some localities, to these may be added two yellow hop clovers, rabbit's foot and scarlet clover.

Many kinds of plants called "clover" are not true clovers. Some of these are the sweet clovers, yellow and white (melilots); the round-head and other prairie clovers (kuhnisteras); the tick clovers (meibomias or desmodiums); the bush clovers (lespedezas); sour clover (oxalis); black-seed clover (medic).

3. Describe a clover-leaf under the headings:

(*a*) The stem (petiole).

(*b*) The leaflets.

(*c*) The little wings at the base of the stem (stipules).

4. Compare the leaf of the common, creeping white clover with that of the red clover.

5. Compare the stems of the two species.

6. From the comparison, discover why white clover thrives better in lawns and old pastures than red clover.

7. Compare the arrangement of the flowers *(a head)* in the common white clover with that *(a raceme)* in the white or yellow sweet clover.

8. Discover the advantage to the white clover of having its flowers in a head.

9. About how many flowers are in a white clover-head?

10. Which flowers open first, the top or the base flowers of the head?

11. As each flower opens and matures, what change takes place in its color and in the shape of its little stem?

12. In what respects is each flower like that of the pea or bean?

13. Which is longer, its calyx or corolla?

14. How many green teeth has the calyx?

15. Use a lens to learn the color, number and arrangement of the stamens.

16. (*a*) Find a matured flower to study the seed-pod.
(*b*) How many seeds are there in each pod?

17. Compare the seed-pod in respect to shape with that of the black medic ("blackseed clover").

18. If you can find the yellow hop clovers or the rabbit's foot clover compare their foliage, stipules, flowers, stems and roots with these parts of the red or Alsike clover.

19. (*a*) Observe a bee visiting clover flowers.
(*b*) State which flowers of the head it selects and why it sips in these and omits the others.

20. (*a*) Can you taste the nectar, *i.e.*, the material of which the bee makes honey, in the clover flower?
(*b*) Which tastes sweeter, the white clover flower or the red?
(*c*) Then why do bees prefer white clover when it produces less nectar?

21. (*a*) Examine the root of red clover.
(*b*) Compare it with the root of the grasses among which it grows.
(*c*) Which descends farther into the ground?

(*d*) In a dry season, why may the clover keep green when the grass looks parched and sere?

22. (*a*) Take up some clover roots very carefully.
(*b*) Examine them for little warts or nodules.

These warty-like growths are the product of a minute fungus or bacterium, too small to be seen without a compound microscope. They are said to be able to store up free nitrogen, a very important part of plant food.

23. Why do farmers sometimes raise rich crops of clover merely to plow it into the ground?

XXIII.—THE TRILLIUM.

A. The Home of the Trillium.

Visit rich woods and observe the trillium in its home.

1. Describe the place where you found trilliums growing, as to shade, soil and plant companions.

2. Describe the position of the plant-stem in relation to the ground.

Plants which grow upright are said to be *erect*.

B. Parts of the Plant.

Carefully remove the soil from the roots and lift the whole plant.

3. Examine and describe the different parts which make the plant.

C. Root and Rootstock.

4. (*a*) Describe the underground parts.
(*b*) Make a drawing of these parts.
(*c*) How were these parts protected during the winter?

5. Compare the underground parts of the trillium with those of the buttercup, clover and hepatica.

6. Of what uses are the roots of the trillium to the plant?

7. (*a*) For the purpose of discovering the uses of the roots to a plant, observe the effect of wind on plants and the effect of withholding water from the roots of potted plants.

(*b*) From these observations infer two important uses of roots to a plant.

8. Mark the position of a trillium in the spring and examine the underground parts late in the autumn.

9. (*a*) Compare the underground parts as seen in the autumn with those as observed in the spring.

(*b*) Account for the early blooming of the trillium.

(*c*) Compare the trillium in this respect with the hepatica and marsh marigold.

(*d*) Infer the uses of the rootstock.

D. The Stem.

10. Describe the stem of the trillium. Draw it.

11. Compare the stems of the trillium, maple, buttercup and geranium.

A plant which dies completely down to the ground after flowering is a *herb* and is said to be *herbaceous*.

12. Using a branch of the maple of nearly equal diameter to the stem of the trillium note similarities and differences in bark and in the arrangement of the internal tissues.

13. (*a*) Place some fresh stems in water colored with red ink or a diamond dye, and describe what takes place.

(*b*) Note the parts where staining appears; and, by cutting a stem every fifteen minutes, the rapidity of the movement of the colored fluid.

(*c*) From this infer how food from the roots is conveyed to the leaves.

E. The Leaves.

14. (*a*) How many leaves has the trillium?

(*b*) How are they arranged on the stem?

The arrangement of leaves in a ring round a stem is called a *whorl.*

(*c*) On what part of the stem are they situated?

15. Observe trilliums forcing their way up through the ground and withered leaves.

16. Describe the modification of the form of the leaves which enables them to come up through the ground.

17. (*a*) Hold a leaf up to the light, and looking through it describe its appearance.

The broad part of the leaf is the *blade.* The strands or lines are called *veins* and a leaf-blade whose veins are arranged in this net-work form is said to be *net-veined.*

(*b*) Draw a leaf.

18. (*a*) To discover the relation of plants to light compare potato stems grown in the dim light or darkness of a cellar with those grown in the light.

(*b*) Infer why the spring is better suited than midsummer to the overground work of the trillium and other "spring flowers."

F. The Flower.

19. What is the color of the flower?

20. What other colored trilliums have you observed?

21. In what respects were they similar to, and in what respects different from, those first described?

22. Which color is the prevailing one in trilliums?

23. Is every part of the flower of the same color?

24. (*a*) How many parts are white or purple?
(*b*) Draw one of these parts.
(*c*) Describe it.

Where convenient cut these forms out of white paper.

One of the leaves of the inner whorl of flower-leaves is called a *petal* and the whorl of such leaves is the *corolla*.

25. (*a*) Examine the green parts of the flower.
(*b*) Distinguish between the green leaves of the flower and the green leaves of the stem.
(*c*) How many green leaves has the flower?
(*d*) Draw and describe a green flower-leaf.

One of the leaves of the outer whorl of flower-leaves is a *sepal* and the whorl of such leaves is the *calyx*.

26. Compare sepal and petal as to color, shape, apex and point of attachment.

27. (*a*) Contrast the position of the calyx in the flower-bud with its position in the open flower.
(*b*) Infer the use of the green flower-leaves.

28. Discover the adaptation in the sepal being wide below and the petal wide above.

29. (*a*) Observe trilliums closely for some time and note what insects, if any, visit the flowers.
(*b*) Describe the position of the insect when you saw it in the flower.
(*c*) Infer from the position and action of the insect why it has visited the flower.
(*d*) Observe closely the insect as it leaves the flower. What do you notice on its body?
(*e*) Discover where and how it got this yellow powder.

This powder is called *pollen* and the small bodies within the flower from which the pollen comes are called *anthers*. The stems on which these anthers are borne are called *filaments* and the whole composed of filament and anther is called a *stamen*.

30. (*a*) Make a drawing of a stamen.
(*b*) How many stamens are there in the trillium?
(*c*) Where are they attached?

31. (*a*) Discover whether the flowers have any odor.
(*b*) Are the odors of different kinds of trilliums the same?

32. (*a*) Discover, if possible, the two means by which insects know of the positions of flowers.
(*b*) Infer one use, at least, of the corolla.

33. What other purposes are served by the color and odor of flowers?

34. (*a*) Describe what else besides calyx, corolla and stamens you see in the flower.
(*b*) With a sharp knife cut this part across where it is thickest.
(*c*) How many cavities do you find?
(*d*) What do you find in these cavities?

35. Observe a trillium until the fruit develops, and discover what these little white bodies in the cavities become.

This central part of the flower is called the *pistil* and the little enclosure containing the white bodies the *ovary*.

The insect and the flower assist each other. The flower provides food (pollen and honey) for the insect, and in return for this the insect performs an important work for the plant. It is the means, through carrying pollen from one flower to another, of helping the flower make seed out of these little white bodies found in the ovary of the flower. This will be studied more fully later.

XXIV.—THE DANDELION.

A continuous study of this plant should be made from its first appearance in the spring till it has ripened and shed its seeds.

1. Does the dandelion grow in the bright sunlight or in the shade?

2. When do the leaves first make their appearance in your district?

3. When does it first bloom?

4. How late in the year have you found it flowering?

A. The Root.

5. (*a*) Carefully dig up from soft soil a dandelion plant with all the earth about it and by carefully moving it up and down in a pail of water wash off the soil.

(*b*) Describe the root as to its parts, length, shape and direction of growth.

6. (*a*) Remove two dandelions from the soil as above. Leave one on a board in the sun, place the root of the other in water and note the effects.

(*b*) Infer from this one of the essential conditions to the life and growth of a root and plant.

7. Why do we water potted plants?

8. Through which part is this moisture taken into the plant?

9. What is one of the uses of the root to the dandelion?

10. (*a*) Strip a dandelion of its very fine rootlets, leaving the thick root. Plant this in a pot.

(*b*) Compare the length of time the plant will live in this condition with the length of time a plant, with all its rootlets intact, will live if similarly planted and watered.

(*c*) Infer from this which part of the root system more particularly performs the function of absorbing water.

11. Account for the development of so many rootlets in the dandelion.

12. Try to pull up a dandelion and infer another purpose served by the root.

13. Cut across the root of a dandelion and note what takes place at the cut ends.

14. (*a*) Mark some dandelions. Examine some of their roots in early spring. Examine similarly the roots of others just after they have cast forth their seeds.

(*b*) Describe what change has taken place.

(*c*) Infer a third use of the root, particularly the thickened part, to the plant.

Such a thickened root as this is called a *tap-root*. Many plants like the dandelion store up nourishment for the purposes of development during the coming season. Examples are the carrot, the turnip, the parsnip and the burdock.

15. Account for the early vigorous development of leaves and flowers of the dandelion.

16. Account also for the vigorous growth of the dandelion during a dry season while most other plants wilt.

17. Compare the root of the dandelion with that of the grass, the mullen and the pea.

18. Make a drawing of the complete root of a dandelion.

B. The Stem.

19. (*a*) Strip the upper surface of soil from the plant and find the stem.

(*b*) Describe it as to length and thickness.

Do not mistake the flower-stem for the stem of the plant.

(*c*) Where is the stem situated with reference to the soil?

20. How does this very short stem differ in appearance from the root?

21. Try to account for the circular markings as well as for the scars or pits found on the stem.

22. Compare these markings with those found on the twig of the horse-chestnut or maple.

23. Compare the main stem of the dandelion with that of the anemone patens, the hepatica, the trillium and the onion in respect to shape, color, hardness, and depth to which it grows.

C. The Leaves.

24. (*a*) Describe the earliest leaves of the dandelion as to shape and position.

(*b*) Where do they spring from?

One of the distinctions between the root and the stem is that the stem does, and the root does not, produce leaves and buds.

25. What advantages are secured for the dandelion by its stem being underground?

26. What is the color of the leaves?

27. Where are foliage-leaves found on plants? Above ground or below ground?

28. Observe the leaves of grass or other plants found under boards or stones or in a dark cellar. What is their color?

29. (*a*) Compare the health and vigor of plants grown under such conditions with that of similar plants grown in the sunlight.

(*b*) Infer from this one condition necessary for the healthy development of the plant.

30. How are leaves fitted by their form to secure proper light exposure?

31. (*a*) Observe the leaves of dandelions growing in short grass; also the leaves of those growing in long grass.

(*b*) Describe any differences you note in the length and position of these leaves.

(*c*) Considering the relation of leaves to sunlight, what is the purpose in this difference of position assumed by the leaves in these two cases?

32. Observe the arrangement of the leaves with reference to each other and note how this arrangement is adapted to secure the greatest surface exposure to sunlight.

33. (*a*) How do the bases of the leaves compare in width with the middle of the leaves and with the apexes?

(*b*) Keeping the same arrangement, what would be the effect of the leaves upon one another if the bases were wider than the other parts, as in the lilac?

(*c*) What adaptation is shown in the relative arrangement of the leaves of the dandelion?

(*d*) Infer from the leaf-position the direction in which the rain-drops and collected dew run from the leaves.

34. Knowing that one of the functions of the root is to absorb moisture from the soil, infer one of the influences that determine the downward rather than the lateral root extension in the dandelion.

35. Compare the leaf-position and the direction of root-development in the dandelion with the same in the beet, the turnip and the rhubarb.

36. Examine a leaf more carefully and determine how the water is assisted in its downward course by the structure of the leaf.

37. In what different ways is this plant adapted to its environment through its leaves?

D. The Flower-stem and Flower.

38. (*a*) Examine the plant in its early development.

(*b*) What do you find closely nestled among the leaves?

(*c*) Describe these buds as to shape and covering.

(*d*) In their early stages, what purpose does the position of the buds among the leaves serve?

(*e*) Infer the use of the outer green parts.

39. How many rows of such green parts do you find in a flower-bud?

40. Examine flower-buds of several dandelions and discover whether they always have the same number of rings of green parts.

These small green outer leaves are called *bracts* and the circle or ring of bracts is called an *involucre*.

41. Examine and describe the stem on which this bud is found.

Such a naked flower-stem is called a *scape*.

42. (*a*) What change takes place in the position of the flower-bud as it develops?

(*b*) How is this effected?

43. Observe a dandelion growing under the edge of a stone or a board, and note the direction of the development of the flower-stem.

44. Observe also the dandelions growing in long grass and in short grass, and note the relative lengths of the scapes.

45. (*a*) How do the scapes in the two latter cases compare in length?
    (*b*) Infer the purpose to the plant of these differences in the length and direction of growth of the scapes.
    (*c*) Infer also one of the conditions essential to the proper development of the flowers.
46. (*a*) Observe the appearance of the flowers at night.
    (*b*) Describe it.
    (*c*) When does this change take place?
    (*d*) How is the closing effected?
47. (*a*) Examine carefully a closed flower. Are all the circles of bracts folded about the flowers?
    (*b*) Describe the positions of the outer and inner circles of bracts respectively.
    (*c*) Infer the purpose now served the flower by the inner circle of bracts.
48. (*a*) Observe the flower on the coming of rain and during cloudy weather.
    (*b*) What change takes place?
    (*c*) Examine a closed flower and determine whether rain and moisture could easily enter it in this condition.
    (*d*) Infer one purpose served by its closing on the coming of rain.
    (*e*) Infer also why it closes at night.
49. (*a*) Mark several flowers with a string or label and note carefully two or three times a day the changes that take place in them.
    (*b*) Describe the changes that take place in the scape.
    (*c*) What purpose is served by this change?

50. (*a*) What change do you observe in the length of the inner bracts shortly before the seeds are matured for dispersal?

(*b*) Why do they elongate?

51. (*a*) How long does the flower finally remain closed before expanding its sphere of seeds to the wind?

(*b*) What then becomes of the bracts?

(*c*) Why do they so change?

(*d*) Describe in detail the functions served by these bracts.

52. Describe the appearance of the flower when opened for the last time.

53. (*a*) Examine the top of the scape on which the flowers are placed in a young flower; also this part in flowers opened and with the spherical collection of seeds.

(*b*) What difference do you observe?

54. Account for the seeds with their appendages assuming this spherical form.

55. (*a*) What now becomes of the seeds?

(*b*) Through what agency are they scattered?

(*c*) In the light of this, account for the lengthening of the scape just before the seed dispersal takes place.

(*d*) How are the seeds aided in their passage through the air?

56. Compare the seeds of the dandelion in this respect with the seeds of the thistle, the clematis, the maple and the ash.

57. Name any other seeds aided in this way by the wind.

58. Pull apart sidewise one of these flower-heads of the dandelion and note its formation.

Each of these small separable parts with the bright yellow strap is a perfect flower. A collection of flowers crowded on the end of a flower-stem, as in this case, is called a *head.*

59. Name any other plants that have their flowers arranged in heads.

60. (*a*) Separate one of these flowers from the head.
(*b*) Describe the several parts.

61. (*a*) Find the part which develops into the seed.
(*b*) Examine this part with the aid of a lens.
(*c*) Describe this part as to shape and surface.
(*d*) Make a drawing of this part.

This part of the flower is the *ovary.*

62. (*a*) Find the hairy part of the flower attached to the ovary.
(*b*) Note to which part of the ovary it is attached.

63. (*a*) As the flower develops what change takes place in this hairy part?
(*b*) What purpose is served by this part?

64. Make a drawing of a seed, with the hairy attachment, as the whole is carried by the wind.

65. What purpose is served by the hooks on the surface of the seed?

This hairy part growing from the upper end of the ovary corresponds to the *calyx* in some other kinds of flowers.

66. (*a*) Examine the colored part of the flower under a lens. Describe it as to color, shape and origin.
(*b*) How many points are there at its upper end?

This part of the flower is the *corolla* and the five points indicate that it is composed of five petals united.

67. Where does the corolla rise from?

68. Describe the remaining parts of the flower found on the face of the corolla.

The part divided at its upper extremity into two curved parts is called the *stigma*, and the stem upon which the curved stigma is borne is called the *style*.

69. (*a*) Examine the stigma and style under a lens.

(*b*) Where does the style arise from?

The yellow bodies below the stigma, and which form a hollow cylinder about the style, are *anthers* and the yellow powder they produce is called *pollen*.

70. Describe the surface of the style and stigma.

71. (*a*) Examine a very young flower towards the centre of the head. Can you see the stigma?

(*b*) Carefully observe these young flowers as they develop and note how the stigma and style develop.

72. When does the stigma open into its two curved parts?

73. Where have the style and outer part of the stigma obtained the pollen you find adherent to them?

74. (*a*) Do you find pollen on the stigma as you do on the style?

(*b*) Why is this?

75. Whether, does the stigma mature, or the anthers shed their pollen, first?

76. Examine more carefully the surface of the outer part of the stigma and style and account for the amount of pollen adherent to them.

The pollen must come into contact with the stigma before seeds are formed in the ovary.

77. (*a*) Observe what insects visit the dandelion. Why do they visit it?

(*b*) Examine closely their bodies while they are on the dandelion. What do you observe on them?

(*c*) Infer how pollen is placed on the stigmas of dandelions.

(*d*) Of what use are insects to dandelions?

E. The Fruit.

78. (*a*) Examine a seed from a ripened head with a lens.

(*b*) Describe it and its appendage.

(*c*) Draw it.

79. (*a*) Observe a seed which has settled among short, thick grass.

(*b*) Which part is uppermost?

(*c*) Why cannot it mount again into the air?

(*d*) What useful purpose is served to the plant by the barbs on the sides of the seeds?

XXV.—A HORSE-CHESTNUT BRANCH.

Observations on the horse-chestnut branch should be continued throughout the year, but more particularly during the periods of leaf and fruit shedding and bud-development.

A. The Branch.

1. (*a*) In what direction do the branches of horse-chestnut trees grow in relation to the trunk?

(*b*) What shape do the branches thus give to the horse-chestnut tree?

(*c*) Compare the general direction of the branches of the horse-chestnut, maple, beech, elm, and Lombardy poplar with reference to the main axis.

(*d*) Account for the difference in shape of the horse-chestnut, beech, and Lombardy poplar.

B. The Buds.

2. (*a*) Examine a branch in the late fall or winter.

(*b*) Describe the positions of the buds.

Those found at the ends of the twigs are called *terminal* buds, while those found on the sides of the twigs are called *lateral* buds.

3. Describe the terminal buds as to shape, size, color and covering.

4. Compare the lateral buds in these respects with the terminal buds.

5. How are the lateral buds situated with reference to each other?

6. Compare the relative positions of the buds of the horse-chestnut with those of the maple and elm.

7. Compare the buds of the horse-chestnut with those of the maple and the elm as to size, shape, covering and method of folding.

C. Leaf-Scars.

8. (*a*) While the leaves are falling in the late fall, examine the twigs.

(*b*) Describe the fresh scars found on the stems at this time.

(*c*) What is their cause?

9. (*a*) Describe the dots found within these scars.

(*b*) How are these dots arranged?

The tree gets its name from the resemblance which these scars bear to a horse-shoe, the dots corresponding to the heads of the shoe-nails.

10. (*a*) Compare as to number the dots in a scar with the leaflets of the leaf fallen from this scar.

(*b*) Infer the cause of these dots.

11. (*a*) What is the position of the lateral buds with reference to these scars?

(*b*) What is their position with reference to the leaves?

D. Bud-Development.

In early spring place some twigs of the horse-chestnut with cut ends in water. Change the water occasionally and keep them in a moderately-warm place. Carefully examine the buds as they develop. Compare this home observation with observation of bud-development on trees and other plants outside.

12. Describe the appearance of the buds as they are about to open and compare their appearance at this stage with that of a few weeks previous.

13. (*a*) Describe the outermost covering of a bud.
(*b*) Try what effect water has on this covering.
(*c*) Infer the use of this gummy covering.

14. Compare the surface of the buds of the elm, maple and ash with that of the horse-chestnut.

15. (*a*) Observe the changes in the appearance of the gum as the bud swells and opens.
(*b*) Discover why it is disappearing.

16. (*a*) Describe the covering found immediately under the gummy substance.
(*b*) How many scales do you find in a bud?
(*c*) Describe their position with reference to each other.
(*d*) What purpose is served by this arrangement?

17. (*a*) Compare the outermost bud-scales as to thickness, shape, length, and colors, with the inner ones.
(*b*) Account for these differences by reference to their position and purpose.

18. (*a*) Describe the parts developing from within the scales.
(*b*) Describe their covering.
(*c*) What is the purpose of this wool-like covering?

19. (*a*) What are the green parts developing from the buds?
(*b*) How many pairs are there?
(*c*) How are the pairs arranged with reference to each other?
(*d*) How are the leaves folded away in the bud?
(*e*) How are the leaflets folded?

20. (*a*) Describe the thick body found in the midst of the leaves in some buds.
(*b*) What does it develop into?
(*c*) At what time of the year are the flowers of the horse-chestnut usually fully developed?

21. (*a*) What position on the bud-stem does the flower cluster always occupy?
(*b*) Do all the buds contain flowers?
(*c*) What is the usual position of those buds containing flowers?

22. What is the difference in appearance of the buds containing leaves and flowers and the buds containing only leaves?

23. (*a*) Observe carefully and describe any changes in the axis on which the young leaves are produced as the bud contents develop.
(*b*) Hence, infer what relation a bud bears to a stem.

24. What becomes of the bud-scales as their contents develop?

E. Scale-Markings.

25. (*a*) Observe carefully the points from which scales have fallen, and describe the effects of their fall.

(*b*) Look at older stems for similar circular markings.

26. (*a*) How often in a year are buds produced?

(*b*) Hence, infer the number of such circular markings that will be found in one year's growth of any stem.

27. Mark off one year's growth; two years' growth; three years' growth, etc., on a twig.

28. Make a drawing of a twig two years old, showing both leaf markings and scale markings; also the positions of the buds.

29. Examine the twigs of the maple and elm for leaf markings and scale markings, and determine the age of the twig.

30. (*a*) Examine the growths of separate years on your horse-chestnut branch, and determine whether they are all of the same length.

(*b*) If the lengths are not the same infer what influences may have caused the difference.

F. Fruit-Scars.

31. (*a*) Examine the branches of the horse-chestnut in the fall when the fruit is dropping or being pulled off.

(*b*) Describe the mark made by the severance of the fruit-stem from the branch.

(*c*) How can you distinguish these marks from those made by the falling of a leaf?

32. Make a drawing of a branch of the horse-chestnut, four years old, showing the buds and the three different kinds of markings.

XXVI.—THE MAPLE TWIG, FLOWER AND FRUIT.

A. The Markings and Their Significance.

1. (*a*) Examine a branch from a maple-tree.
   (*b*) What markings are found on this twig?
   (*c*) Show the bud-scale scars.

2. (*a*) Show the part which grew last year.
   (*b*) Explain your reason for selecting this part as that which grew last year.

3. Describe the other markings.

4. Compare the markings on a maple branch with those on a horse-chestnut.

5. Infer the cause of these marks.

6. (*a*) Cut the part which grew last year, across at right angles to its length.

A section or cutting at right angles to the length of the branch is a *cross-section.*

A thin section cut along the diameter is called a *radial longitudinal* section, and one cut lengthwise across the diameter and towards the outside is called a *tangential longitudinal section.*

The spongy central part is called the *pith* or *medulla.*

   (*b*) Describe the cross-section particularly.
   (*c*) With a pin or sharp-pointed knife examine the central part.

7. With a sharp knife make the three kinds of sections. Describe each.

8. Distinguish the three areas—bark, wood, pith.

9. Take a fresh stem and identify the line of separation between the bark and wood in the cross-section.

The cylinder of soft, spongy tissue in the centre of the branch is the *pith.* It is composed of *cellular tissue.* The outside layer of the branch is the bark.

The hard, solid part of the branch between the pith and the bark is *wood.* It is composed of *tissue* made up of *woody fibres* and *vessels.*

10. Draw a cross-section of the stem showing the three distinct parts.

11. Using a lens compare the cross-section of a stem, one year old, with that of a stem several years old.

12. Make longitudinal sections of parts of twigs of various ages; compare them and draw them.

B. The Medullary Rays.

13. (*a*) Notice any radial markings to be seen in the longitudinal as well as in the cross-sections of the twigs.

(*b*) Where are they found?

The bands of cellular tissue proceeding from the pith, or medulla, to the surface are called *medullary rays*.

14. Compare the wood in the medullary rays with that about them.

C. The Lenticels.

15. (*a*) Observe the specks which are found in the bark of twigs.

(*b*) How are they formed?

(*c*) How are they arranged?

The loose mass of cells found in the bark are the *lenticels*. These permit an interchange between the gases within the plant and the external air.

D. The Bark.

16. Make a cross-section of a twig of basswood.

17. Compare this cross-section with that of the maple twig.

18. Examine the bark of the basswood twig to discover its parts.

19. Discover if the maple twig has the same parts in its bark.

20. Make a cross-section and a longitudinal section of the stems of the tulip and adder's tongue and as soon as possible make similar sections of the stems of Indian-corn and asparagus.

21. Make drawings of these sections.

22. Compare them with similar sections of the maple and horse-chestnut twigs.

23. Contrast the arrangement of the woody part in the stem of the Indian-corn and in a branch of the maple or horse-chestnut.

24. (*a*) When trees and shrubs are in full leaf, discover where there is much sap in the branches.

(*b*) Infer where growth is taking place.

Stems like the maple and horse-chestnut are said to be *exogenous*; the wood-bundles in such stems are arranged in circles, each new circle being deposited outside of the circle of last growth. Plants producing such stems are called *exogens*.

Stems like those of the Indian-corn and tulip are said to be *endogenous*. The wood-bundles in such stems are not arranged in circles, but are developed irregularly throughout the stem. Plants producing such stems are called *endogens*.

E. The Arrangement of the Buds.

25. Point out the position of the various buds on the maple twigs.

26. (*a*) Observe the terminal bud and discover into what it is developing.

(*b*) Note the way in which the new leaves are arranged along the stem.

(*c*) Compare this arrangement with that of the leaves of other trees in the neighborhood, as the horse-chestnut, elm, basswood and beech.

27. Observe the lateral buds on the stem of last year's growth and discover what they will become.

28. As the new stem develops and the season advances observe the lateral, or axillary buds.

29. How does the new stem differ from that of last year?

30. Compare the structure of the new stem with that of a sunflower, geranium or flax.

F. The Flower.

31. Examine the flower-cluster.

32. Select a single flower and describe the parts present.

33. Compare the parts of this flower with those of other maple-flowers of the neighborhood.

34. Note the date of the blossoming of the tree and compare it with the time other trees blossom.

G. The Fruit.

35. Watch the development of the fruit.

Winged fruit like that of the maple, ash or elm is called a *key* or *samara.*

36. Draw a maple key.

37. Compare the shape and size of the keys with those of other maples of the neighborhood.

38. Compare the fruit of the maple with that of the elm.

39. Infer why these fruits have wings.

40. Find a sprouting maple-seed.

41. Note the time when the seeds of different kinds of maple-trees may be found sprouting.

42. In what kind of soil does the maple grow to greatest perfection in your neighborhood?

H. The Leaf.

43. Where do the new twigs grow?

44. Of what use are twigs to trees?

45. Count the leaves on a single branch.

46. Discover how the twigs are enabled to support the leaves.

47. Try to discover how twigs are able to resist gusts of wind.

Tie a piece of twine to a weight such that the cord will break when an attempt is made to lift the weight with a jerk. Then attach the same string to the weight by means of an elastic band and by a jerk, even more vigorous than before, raise the weight. The string remains unbroken.

48. Explain why the string does not break when the rubber band is used. Apply the knowledge gained to answer No. 47.

XXVII.—THE APPLE TWIG.

Observe the apple-tree in winter or early spring. Compare its twigs with those of other trees as to shape, size, firmness and direction of growth. Collect several twigs; compare their form and markings. Develop the buds on some of them by keeping their cut ends in water in a place where the water will not freeze. Keep the others dry for comparison later.

1. (*a*) Observe the rings on the main branch; also on the twigs.
   (*b*) Infer the cause of these rings.
   (*c*) Note the number of times these rings occur on the branch or twig and calculate its age.
2. Compare branches of different ages.
3. (*a*) Select a branch showing two years' growth.
   (*b*) Observe the difference in the markings of the two years' growth, and discover, if possible, the cause of the difference.
4. (*a*) Examine the terminal bud.
   (*b*) Observe the bud unfold.
   (*c*) Note its contents.
5. As the twig lengthens observe the position of the leaves.
6. Compare new buds forming in the axils of the leaves with older buds.

7. (*a*) Observe the leaf-scars from last year and the buds above them.

(*b*) Discover into what these buds will develop.

The buds at the end of the twigs are *terminal* ones. Those on the sides of the twigs are *lateral*, and as these always grow in the axils of leaves they are said to be *axillary*.

8. (*a*) Observe the buds nearest the terminal bud.

(*b*) Discover why these develop much more readily than do those lower down.

(*c*) Discover also why some are dormant.

9. Discover why some of the twigs grow so much longer than others.

10. Draw two twigs:

(*a*) Showing the new twig as it lengthens with the leaves spread out.

(*b*) A twig of last year's growth.

11. (*a*) Observe the broken ends on some of the twigs or smaller branches.

(*b*) Note the age of the part on which they are found.

(*c*) Compare these broken ends with buds.

(*d*) Discover the reason for the difference.

(*e*) Do any of these ends appear as terminal?

(*f*) Infer the reason.

The short projections with broken ends are the *fruit-spurs*.

12. (*a*) Observe the work of the fruit-spurs.

(*b*) Discover why they cannot bear fruit every year.

13. (*a*) Describe the buds sent out by the spurs not bearing fruit.

(*b*) Discover into what these buds develop.

14. (*a*) Describe the markings left by the flowers that did not set.

(*b*) Compare these with the other markings on the branch.

15. (*a*) Observe and compare several branches and twigs.

(*b*) Discover:

(1) The age of the twigs.
(2) The number of apples each bore.
(3) The probable fruit-spurs for next year.
(4) Where the blossoms did not set.
(5) The dormant buds.
(6) Where apples fell before they were fully developed.
(7) Where the fruit-spurs were apparently changed and became branches of strong growth.
(8) Places where terminal buds were injured and lateral buds developed into fruit-buds.
(9) Accidental markings of any kind.

16. Make drawings of the different parts of the branch.

XXVIII.—THE APPLE AND THE CODLING-MOTH.

A. The Apple-Tree.

1. (*a*) Observe apple-trees.

(*b*) Describe an apple-tree.

2. Compare apple-trees with other fruit-trees as to size and shape.

3. Make enquiries to learn at what age apple-trees begin to bear fruit and how many years they continue fruit-bearing.

4. How does the tree get itself ready during the summer for fruit-bearing in the following year?

5. Plant seeds and observe the growth of the young trees.

6. (*a*) If opportunity offers, observe how trees are grafted.
   (*b*) What is the purpose of grafting?

7. (*a*) Observe the process of pruning trees in an orchard.
   (*b*) Why are fruit-trees pruned?
   (*c*) At what times of the year are they pruned?
   (*d*) Why are these the proper times?

8. (*a*) From what sources does the tree derive the materials which go to form the apples?
   (*b*) How does apple-bearing affect the soil in which the trees grow?
   (*c*) Observe how a good farmer treats the orchard soil each year.
   (*d*) Examine why it is necessary to treat it in this way.

B. The Apple.

9. (*a*) Examine an apple.
   (*b*) Discover how it was fastened to the twig.
   (*c*) Describe its color, shape, hollows, size.
   (*d*) Describe the stem. Discover why it is so hard and tough.

10. Through what parts of the tree was nourishment carried from its roots to the fruit?

11. Discover what are the five little brown things to be found in the eye; also the tiny, dried, thread-like things.

12. At the proper time of the year, observe the development of the apple to determine what parts of the flower go to form the following:

(*a*) The core.

(*b*) The fleshy part of the fruit.

13. Tell how each of the other parts assisted.

14. How does the bee assist?

15. How can you tell when an apple is ripe?

16. Of what use are the following to the apple:—

(*a*) The skin?

(*b*) The fleshy part or pulp?

17. What purpose does the production of the apple serve to the apple-tree?

18. What is the use of the fleshy part of the apple to the tree?

19. (*a*) In relation to the tree, which part of the fruit is most important?

(*b*) Why?

20. What is the general shape of the apple?

21. Compare it as to shape with other fleshy fruits.

22. Try to account for the prevailing shape in fruits.

23. (*a*) Cut your apple crosswise.

(*b*) Draw one half.

(*c*) Show the five-chambered core.

C. The Seeds.

24. (*a*) Examine the seeds and note their color.

(*b*) Compare the color of seeds in ripe and in unripe apples.

25. (*a*) Put the parts of the apple together and cut it through from stem to eye.
    (*b*) Separate and examine the divisions.
    (*c*) Describe the seed-chambers, their position in the apple, their length, their width, their walls.
    (*d*) Infer why they are placed where they are.
26. Discover the use of these walls to the seed.
27. (*a*) Examine the seed; note its two coats, its smoothness.
    (*b*) Enumerate the various means taken to protect the seed.

D. General Observations.

28. (*a*) Observe the different varieties of apples grown in your district.
    (*b*) Name these varieties and describe as many of them as you can in respect to shape, color, flavor, firmness and time of ripening.
    (*c*) Name the best winter varieties grown in your neighborhood.
    (*d*) Discover why they are the best.
29. Make observations regarding the following:—
    (*a*) How apples are picked and packed.
    (*b*) How they are stored.
    (*c*) The best kind of apples for shipping.
    (*d*) The different uses made of apples.

E. The Codling-Moth.

30. Procure an apple that contains or has contained a larva of an insect, most probably the codling-moth.
31. (*a*) Cut the apple across.
    (*b*) Cut some in different directions to discover the path of the insect.

32. (*a*) Observe the larva.
(*b*) Describe it.

33. Examine the apple to discover, if possible, how the insect entered it.

34. Why did it enter the apple?

35. Discover where the insect got out of the apple.

36. Examine other apples similarly infested to determine whether these insects always enter at the same point of the apple.

37. Examine the same apples from day to day to discover how long the larvæ remain in the apples.

38. (*a*) Search under the bark-scales on the trunk of apple or pear trees between October and May for the cocoons of these larvæ.
(*b*) Describe the appearance of the cocoons.

39. (*a*) Collect a number of cocoons, keep them in a cool place, and observe the moths emerging in the spring.
(*b*) Describe the moth as to color and size.

NOTE.—The codling-moth is distinguished by having on a brownish spot on the front wings near the end, a little horseshoe of bright, copper-colored scales. The rest of the front wings is pale gray, finely specked.

40. (*a*) Compare the color of the moth with that of the bark of the trees on which it is commonly found.
(*b*) What adaptation to environment is effected through its color?
(*c*) When does the moth fly, by day or by night?

41. (*a*) In early June examine young apples to discover the eggs of this insect.
(*b*) Describe the appearance of the eggs as to color and size.

(*c*) Are they laid singly or in masses?

(*d*) Are the eggs found on other parts than the apples?

(*e*) When are the eggs laid with reference to the falling of the petals?

42. Write the life-history of the codling-moth.

43. Observe the different means used by orchard-owners to destroy these insects.

NOTE.—The common method of destroying this pest is to spray the trees with a poisonous solution, the purpose being to kill the newly-hatched larva before it eats its way into the fruit.

44. (*a*) If the trees are sprayed when the flowers are open what effect will the poison have on visiting insects?

(*b*) If the insects are not permitted to do their work on the blossoms of the tree what will be the effect upon the crop of fruit?

45. (*a*) Describe the actions of woodpeckers on apple or pear trees.

(*b*) Examine where they have been pecking to discover what was under the bark-scales.

(*c*) Infer why the woodpecker and other like birds should be protected.

XXIX.—WOOD.

Each pupil should have a simple lens. There should also be a compound microscope and a set of bench tools.

A. Study of the Structure and Growth of Wood with the Formation of the Grain.

1. With a fine saw, cut cylinders of pine, maple, oak, etc., from small trees or fair-sized branches and remove a part of the bark.

Some of the cylinders should have knots and others should be sun-dried to show "checks."

2. Split some and polish the surface.

3. What is the material of which each block is composed?

4. From what kind of tree has each been taken?

5. Examine and describe the different surfaces of the block.

The white wood next the bark is the *sapwood*. The wood in the interior is the *heartwood*.

6. Compare the surfaces of various blocks, noting their resemblances and differences.

7. (*a*) Examine the circular surfaces of each block more closely.

(*b*) What is there in common about both areas?

(*c*) Infer the way in which these rings have been formed, and the reason why the two areas are of different colors.

8. (*a*) During what season of the year does a tree grow?

(*b*) What conditions of the growing-time are the most favorable for growth?

(*c*) Infer, then, the reason why some of the rings are thicker than others.

9. Examine a cylinder cut fresh from a young tree to determine which of the rings has grown last.

10. Observe the sap between the bark and woody part.

B. Medullary Rays.

11. (*a*) How does a tree show a record of the different periods of its growth?

(*b*) What means have you of judging of the age of a tree?

(*c*) Compare the width of the rings in the various cylinders and infer which tree grew fastest.

12. (*a*) Observe other markings on the circular surface.
(*b*) Describe them.
(*c*) Infer why these lines are called rays.

13. (*a*) Using a strong knife try to split the block in various directions.
(*b*) Along what lines do the blocks split most easily?

14. (*a*) Which kinds of wood split easily and which with difficulty?
(*b*) Find the reason in each case.

15. (*a*) Try to split a block with knots.
(*b*) Examine the split surface and explain why it was difficult to split.

16. (*a*) Cut slabs from the cylinders.
(*b*) Explain why the blocks may be split in these planes.
(*c*) Examine and describe the split surfaces.
(*d*) What relation do the lines on the split surfaces bear to the rings of growth?

17. Compare the graining in the different kinds of wood.

18. On what does the nature of the graining depend?

19. Observe the effect of the following upon the graining of the wood:—
(*a*) The thickness of the annual rings.
(*b*) The regularity of these rings in shape.
(*c*) The straightness of the stem.
(*d*) The presence or absence of knots.
(*e*) The coarseness or firmness of the wood-fibres.

20. (*a*) Cut some of the cylinders into quarters.
(*b*) Make slabs from these in various planes.
(*c*) Compare the graining in the several cases.

21. Which do you consider the most beautiful grains?
22. Try to imitate them in drawings.
23. (*a*) Cut the different woods with a knife or chisel.
    (*b*) Which are hard to cut and to work?
    (*c*) Which are easy to cut and to work?
24. (*a*) Polish one of the surfaces by rubbing the slabs with fine sandpaper.
    (*b*) Compare the various kinds of wood as to their adaptation for taking a polish.
25. From your observations, suggest uses for the different kinds of wood and discover why they are thus used.
26. Make a collection of different kinds of wood and label each specimen with the time and place of collection.

XXX.—LEAVES.

A. Relation to Sunlight.

1. Collect leafy twigs of the maple, elm and horse-chestnut.
2. (*a*) On what part of the plant were these leaves found?
   (*b*) Where were they growing, with relation to the ground?
   (*c*) What is their color?
3. (*a*) Examine grass-leaves that have been covered by a board for a few days.
   (*b*) What is their color?
4. (*a*) Place a house plant (geranium) in darkness for eight or ten days.
   (*b*) Observe the changes that take place.
5. From these observations, infer the relation of the green color of the leaf to sunlight.
6. Compare the form of leaves with that of the stem of the plant.

7. In house plants, shrubs and trees, observe what position the leaves generally take relative to sunlight.

8. From observations of the *position*, *color* and *form* of leaves, infer one essential condition of their healthful activity.

9. (*a*) Examine a spray of the maple.

(*b*) Compare the different leaves on the spray as to:

(1) *Shape.*

(2) *Size.*

(3) *Length* of petiole.

10. Supposing all the leaves on this spray were of the same size and with petioles of equal length, how would the amount of sunlight received by some of them be affected?

11. Assuming sunlight to be necessary to the life of the leaf, account for the varying sizes of the blade and the difference in length of the petioles.

12. (*a*) Examine the leaves of a house plant, as a geranium or shamrock, grown in window light.

(*b*) What is their position relative to the sunlight entering the window?

(*c*) Turn the pot around and after some days note any change in the position of the leaves.

(*d*) Infer the cause of this change of position.

B. The Life-Work of the Leaf.

13. (*a*) Place a vigorous leaf (freshly cut) so that its petiole may pierce a piece of cardboard and enter water contained in a tumbler. Cover the blade with another tumbler inverted and resting on the cardboard. After some time examine the inner surface of the upper tumbler.

(*b*) What do you observe?

(*c*) Where has the moisture come from?

14. Where does the leaf on the stem obtain water?

15. Observe the effect on the leaves of withholding water from a potted plant.

16. From the above experiment, account for the withering of the leaves of the potted plant.

This process of evaporation of water from the leaf is called *transpiration*. The water or vapor passes off from the leaf through minute openings, or *stomata;* these are found on both surfaces of the leaf, but are usually most numerous on the under side.

17. (*a*) Set in a window, where there is plenty of direct sunlight, a tumbler containing water and having the blade of a vigorous leaf immersed in it.

(*b*) After an hour or so examine the leaf. What do you observe rising from and on the surface of the leaf?

(*c*) Now, set the tumbler with the leaf in darkness and after an hour examine it again.

(*d*) Compare this observation with that made when the glass and leaf were in sunlight.

(*e*) Again, place the glass with the leaf in direct sunlight and after some little time observe what takes place.

(*f*) From these observations infer the condition for this activity in the leaf.

These bubbles found on and rising from the leaf are mostly bubbles of oxygen. The setting free of this gas from and by the leaf is an indication of work being performed by the leaf in the process of digesting its food.

18. (*a*) Have a couple of fruit-jars with closely-fitting tops. Burn a candle in one until it will burn no longer. Relight it and again place it in the jar.

(*b*) What is the result?

19. (*a*) Place in this jar, containing a little water and the product of the burned candle, a few sprays of mint or other green plant. Seal it and set it aside for two or three days in the sunlight. Then test the gas within the jar by lighting a candle and placing it in the jar.

(*b*) What is the result?

(*c*) Is the gas in the jar the same now as that in the jar when it was set away?

(*d*) Account for the result you observe.

20. While awaiting the results of the above experiment, take another bottle or jar and place a little lime-water in the bottom. Burn a candle within the bottle until it will burn no longer. Now, shake the bottle vigorously, holding the hand over the mouth of the bottle.

21. Examine the lime-water.

22. What changes have you observed?

The gas which enables the candle to burn is oxygen. Oxygen is produced, and carbon dioxide is assimilated, in the little cells of the leaf through the action of small green bodies in the cells, which give the green color to the leaf.

23. From these experiments, what do you infer to be one of the foods of the plant taken in by the leaf?

24. What gas in the process of food-digestion is given off into the air?

25. (*a*) By means of a straw or glass tube, cause the air from your lungs to bubble through some lime-water in a glass. Continue the bubbling for some time. Then examine the lime-water.

(*b*) What change has taken place?

26. From these facts, infer the effect of growing-plants upon the air of a room.

The advanced class may continue experiments with a view to demonstrate that growing-plants are healthful in living-rooms during daylight, but injurious at night.

27. What three facts have been learned about the work of the leaf?

C. Relation between the Leaf and the Root.

28. Examine the position of the leaves of the turnip, beet, radish and rhubarb.

29. (*a*) What is the course of the collected rain-drops or the trickling dew on the surface of these leaves?

(*b*) What relation do the creases in these leaf-blades bear to this course of the water?

30. (*a*) Now, examine the roots of these plants.

(*b*) What course do they take in their growth?

(*c*) Infer a reason for this.

31. (*a*) Examine the relative position of the apex and base of the leaves on maples, elms and willows.

(*b*) Generally, which is on the higher level?

(*c*) Infer the course taken by rain-water on such trees.

32. (*a*) Examine the roots of these trees and state the direction of their growth.

(*b*) Infer why their development should be lateral rather than vertically downward, and where a fertilizer should be placed intended to reach the roots of a large tree.

33. From these observations, what general conclusion can be drawn with reference to the relation between the position of the leaf and the direction of the development of the roots?

D. The Relation of the Position of the Leaf to the Light.

34. (*a*) Examine the leaves of an erect, unbranched plant such as the mullen.

(*b*) What is the position of the lower leaves relative to the stem?

(*c*) What are the positions of the leaves higher up the stem?

(*d*) What would be the effect on the amount of sunlight received if all the leaves had the horizontal position of the lowest leaves?

35. What adaptation of the leaf to sunlight is effected in this plant?

36. Compare the leaves on the same mullen-stem as to size.

37. What adaptation to environment is evident in this difference of size?

38. Make similar observations of the shepherd's-purse.

39. Make a list of plants in which you have discovered similar adaptations.

40. (*a*) Examine the leaves of the prickly-lettuce or wild-lettuce.

(*b*) How does their position relative to sunlight compare with that of the mullen?

(*c*) Account for this modification.

Modifications such as these are not due to accident, but are rather definite modes of adjustment to environment.

E. Relation between Width of Leaf-blade and the Number of Vertical Whorls on an Erect Stem.

41. (*a*) Examine the leaves of the sunflower and the lily.

(*b*) Compare their leaves as to the following:—

(1) Proportionate length of blades.

(2) Width of blade.

(3) Mode of attachment.

42. How do the number of vertical whorls of leaves in the one compare with that in the other on the same length of stem?

43. Make similar observations of the leaves of other erect plants.

44. What is your conclusion with respect to the relation between the width of the blade and the number of vertical whorls on the erect stem?

45. Make a list of plants observed in this respect. What adaptation here becomes evident?

F. Relation of Length of Petiole to Leaf-position.

46. (*a*) Examine the bellflower (*Campanula*), or early saxifrage, or robin's daisy, or plantain, or dandelion, from the direction in which the sunlight strikes it.

(*b*) Describe its appearance from this view-point.

(*c*) Account for the formation of the rosette of leaves.

47. What purpose is served by its having the lower leaves with long petioles and the higher ones with shorter ones?

48. Similarly, observe the leaves of the begonia.

49. Make a list of plants in which you have observed a similar adaptation.

XXXI.—SEEDS.

1. In the fall of the year, collect a number of seeds of each of the following:—beans, peas, Indian-corn, morning-glory, maple, squash. Bottle and label each kind.

(*a*) Compare the different ways in which these seeds are protected by the plant.

(*b*) Soak some of each for a day before examining them.

A. External Markings.

2. (*a*) Observe an unsoaked bean.

(*b*) Describe its color, shape and surface.

3. (*a*) Examine the surface to discover a part different from the rest.

(*b*) Find a corresponding part in a pea.

(*c*) At the first opportunity examine a green pod containing beans or peas and infer the cause of this scar.

This scar on the bean, pea, and other seeds is called the *hilum.*

4. With a lens discover a minute orifice near the scar.

The small opening is called the *micropyle.* Consult a dictionary to learn the root of this word. Most of the terms used in science are derived from Greek and Latin roots. Knowing that *micros* means small aids in remembering and understanding micropyle, microscope, microspore, micrograph, microbe.

5. (*a*) Discover also a small protuberance near the scar.

(*b*) Describe its position with respect to the micropyle.

B. Parts of a Seed.

6. (*a*) With a needle or sharp knife, remove the covering from a bean which has been soaked for a day.

(*b*) Where is the coat connected with the rest of the seed?

7. (*a*) Separate the inner portion of the seed.

(*b*) How many parts do you find?

(*c*) Describe the form and position of each part.

The two thick parts are the *cotyledons* or seed-leaves. The small part between these cotyledons in the bean and the pea, pointing towards the micropyle, is the *caulicle.* The other small part between the cotyledons is the *plumule.* The cotyledons, caulicle and plumule together constitute the *embryo.*

8. Draw:
   (*a*) The embryo of the bean in different positions.
   (*b*) The embryo with one cotyledon cut away so as to show the caulicle and plumule.
   (*c*) The caulicle and plumule as seen under a lens. Name each part as it is drawn.
9. (*a*) Examine the pea and compare it as to markings and contents with the bean.
   (*b*) Draw the parts observed as in the bean.

C. Dicotyledonous Seeds.

10. (*a*) Treat the castor-bean in a similar manner to the pea and the bean, and examine it as to color, shape, external markings, number and kinds of coats.
    (*b*) How many parts are found within?
    (*c*) Describe the form and relative position of each part.
    (*d*) Draw the parts and name them as in the case of the bean and pea.
11. (*a*) Describe minutely the appearance of the inner surfaces of the two halves of the inner portion of the seed.
    (*b*) Make a drawing of one of these surfaces, marking in all the lines you observe.
    (*c*) What does this face resemble?
12. (*a*) By means of a sharp knife try to remove this thin face.
    (*b*) Are these leaf-like surfaces separable from the part underneath?

These thin, leaf-like bodies are the cotyledons and the two thickened masses on which they lie are the food for the development of the seed. This food is called *albumen*.

13. Where are the cotyledons situated in relation to the two whitish bodies?

14. Describe the parts found in this seed which are not in the bean or pea.

15. (*a*) In what respects are all the seeds examined similar?

(*b*) In what respects are they different?

16. How many cotyledons are found in each?

Seeds containing *two cotyledons* are *dicotyledonous* seeds.

17. What was found in the castor-bean that was not found in the common bean or the pea?

Seeds like the castor-bean containing albumen outside the embryo are said to be *albuminous*. Those like the bean and the pea containing no albumen outside the embryo are said to be *exalbuminous*.

18. (*a*) Examine other seeds, such as those of the squash, sunflower, almond, maple, buttercup, etc., and compare them with those already examined.

(*b*) Classify them as albuminous or exalbuminous.

D. Monocotyledonous Seeds.

19. (*a*) Treat Indian-corn in a similar manner to the seeds examined.

(*b*) Describe the external features of the grain.

20. (*a*) Make a longitudinal section perpendicular to the flat sides and through the middle of the grain which has been soaked for a day or more.

(*b*) Observe the strong external covering composed of the united coats of the seed and fruit.

(*c*) Make a drawing of the cross-section.

21. (*a*) Strip off the entire covering from the paler face of the soaked grain and remove the whitish body lying on the face of the grain.

(*b*) Of how many parts is it composed?

(*c*) Describe each of these parts as to form and relative position.

(*d*) Make drawings of these and name each part shown.

(*e*) How many cotyledons are present?

22. What is found within the seed-coats in addition to the embryo?

23. What seed in Section C does it resemble in this respect?

24. To which class of seeds—albuminous or exalbuminous—does it belong?

25. In what respect does the embryo of Indian-corn differ from that of each of the seeds previously examined?

Seeds such as the corn which contains only *one* cotyledon are *monocotyledonous seeds.*

26. Examine similarly onion-seed, wheat, etc., and compare each with Indian-corn.

27. Plant several seeds of the kinds examined and watch their development to determine the function of each part.

XXXII.—GERMINATION.

1. (*a*) Place some beans, peas and corn in dry sand and leave for five or six days in a warm, dry place.

(*b*) Examine these seeds to discover whether any change has taken place.

2. (*a*) Place similar seeds about one inch deep in moistened sand or sawdust. Add a little water each day and keep in a warm place.

(*b*) Note what changes, if any, have taken place during five or six days.

3. Plant similar seeds in moistened sawdust and place within a refrigerator, or, if during winter, place outside and note what changes, if any, occur in the seed-development.

4. From these experiments infer the proper conditions for the growth of the embryo.

5. (*a*) Fill a box about twenty inches long, eight inches wide, and six inches deep, with sawdust or earth and plant in it a dozen of each of the following seeds:—Common bean, pea, corn, radish, onion, squash and two or three castor-beans. Soak the seeds in tepid water for a day before planting. Place them about an inch deep and moisten the contents of the box each day. Keep in a warm place; for example, in a south window of a warm room if the experiment be performed in winter or very early spring.

(*b*) Examine some of the seeds daily after the second day, by gently stripping the sawdust or earth, and note carefully what changes have taken place.

6. Make drawings as soon as any signs of growth begin, and continue to make drawings showing particularly the successive stages in the development of each of the different kinds of seeds. Mark under each drawing the number of days which have elapsed since planting.

7. At what point did the seed-coat first break?

8. Which part of the kernel first emerged?

9. Which part of the seed first appeared above the surface?

10. In which seeds did the seed-coat emerge above the surface?

11. (*a*) In which seeds do the cotyledons appear above the ground?

(*b*) How do the common bean and the pea compare in this respect?

(*c*) Discover the reason for this difference.

12. (*a*) Observe carefully the general appearance of the cotyledons in the bean, pea, and squash as growth continues.

(*b*) What change is taking place?

(*c*) From this what would you infer to be the function of these cotyledons?

13. (*a*) Observe the corn and castor-bean under similar conditions to discover what is the use of the albumen in the corn seed and in the castor-bean seed.

(*b*) What has become of the caulicle in each of the seeds?

14. In what manner has the plumule developed?

15. From these observations infer the function of the caulicle; also of the plumule.

16. How do the cotyledons emerge from the coat in the case of the squash, bean, radish and castor-bean?

17. Compare the cotyledons of the different seeds with their plumule-leaves; also with their fully-developed foliage-leaves as to size and shape.

18. In which direction does the plumule of each seed develop?

19. In which direction does the caulicle develop?

20. (*a*) Turn a seed in the sawdust or earth so that the positions of the caulicle and plumule, relative to the earth, are reversed, and note what takes place.

(*b*) Describe this action.

This growth of the embryo of the seed until the plantlet has secured a foothold in the soil and gathers food for itself is called *germination.*

21. Observe the germination of any seeds which are common about the premises, such as those of the elm and maple found in lawns and along fences.

22. Other means of observing germination are the following:—

(*a*) Fill a box a foot long and three inches wide, one side of which is formed by a pane of glass sloping obliquely upward from the middle of the bottom, three-fourths full of moss or peaty earth and sow seeds along the margin of the glass. Observe how the roots spread over the glass.

(*b*) Procure a sheet of flannel six inches wide and several feet long. Crease it into folds and run a seam through each fold about four inches from the margin. Place seeds of various kinds in the flannel between the folds. Place it over a vessel of water so that the folds may be in the water. The seeds will be kept moist and should be observed from day to day.

XXXIII.—THE POTATO.

Make observations in a potato-patch when the plants are in various stages of development.

A. Planting.

1. Observe how the ground is prepared before the potatoes are planted.

2. Observe how potatoes are cut for planting.

3. What must be on each cutting?

4. How deep in the ground are potatoes planted?

5. What is the proper time for planting?

6. Dig up plants at various stages of development and observe how the roots spread.

7. Distinguish the roots from the underground stems.

8. What is the use of heaping earth around the growing plant?

B. The Flower and Fruit.

9. Observe on what part of the plant the flower is found.

10. (*a*) Describe the flower.
(*b*) Draw it.

11. Observe the flower of the tomato and compare it with that of the potato.

12. (*a*) Observe the fruit if it can be found.
(*b*) Compare its fruit with that of the tomato and also with a gooseberry.
(*c*) Describe and draw it.
(*d*) Into what does it ripen?

13. Distinguish between the tuber and the fruit.

Potatoes may be grown from seeds. Into a box put some soil; sow the seeds; just cover them with earth and keep it moist.

14. Discover why a potato or part of one is planted rather than the seed.

15. Compare the raising of potatoes from cuttings with that of onions from seeds and bulbs.

C. The Tuber.

16. How are the buds (eyes) arranged on the potato tuber?

17. (*a*) Discover on which part of the tuber the buds are most vigorous.

(*b*) Why are the buds more numerous at the outer than at the inner end?

18. Compare these buds with those on stems growing above ground.

19. (*a*) Dissolve a few crystals of iodine in an ounce or two of water and add a drop to the freshly-cut surface of a potato.

(*b*) Observe what takes place.

The color reaction (blue) is the test for the presence of starch.

20. Why is the potato a valuable food?

21. At home try to discover the best method of boiling potatoes.

Try putting them into cold water and letting them cook, and putting them into boiling water to cook, to discover the preferable mode.

XXXIV.—GRASS.

Wheat, oats, barley, rye, millet, rice, Indian-corn, foxtail, and chess are grasses as well as timothy or red-top, but the plants usually thought of when we speak of grass are those suited to the lawn, pasture or meadow, except the clovers.

1. (*a*) In a well-known little poem called "The Song of the Grass" the grass is represented as singing, "I come creeping." What character does grass possess that enables it to "come creeping"?

(*b*) Dig up grass plants and study them to find where such power resides.

2. (*a*) Observe pieces of land that have not been cultivated for a year or two.

(*b*) Note the succession of plants—first, the erect weeds; bye and bye, the grass.

(*c*) How is it that the slender, lowly grass can drive off the stout weeds?

3. (*a*) Examine roots of different kinds of grass to discover some like the foxtail that cannot "creep."

(*b*) In the cleared pieces of ground referred to in No. 2 (*a*) which kinds of grass usually appear first—the creeping or the non-creeping ones?

4. Try to discover the reasons why foxtails, chesses and annual panic grasses precede the creeping kinds in the occupation of a neglected garden.

5. Dig up carefully, wash clean, dry and preserve two or more grass plants to show clearly the difference in the roots between the annual and the perennial grasses.

6. (*a*) Which class—annual or perennial—has generally larger seeds?

(*b*) More numerous seeds?

7. Examine grasses to find any that store nourishment for another season in their roots.

8. (*a*) In what ways are the perennial grasses most useful to man?

(*b*) How do the annual grasses best serve him? (See the note at the head of this lesson.)

9. Defend or refute the statement that the grass family is the most useful family of plants in the world.

Oats.

10. (*a*) Plant some oats and beans in the manner suggested on page 129 to watch their germination and early development.

(*b*) Note the differences in the young plants.

11. (*a*) Examine plants of oats when the flowers or fruit have developed.

(*b*) Is the stem hollow or solid?

(*c*) Can you find any part where the stem is solid?

(*d*) What marks the outside of the stem in such places?

12. Trace the connection between the leaves and the solid zones of the stem.

13. Compare the leaf of the maple or willow or plantain with that of the oat.

14. (*a*) To what part of the other leaf does the sheath of the oat-leaf correspond?

(*b*) How are the leaves of the oat arranged on the stem?

(*c*) Compare this arrangement with that of the leaves in the maple.

(*d*) How does the sheath of a grass-leaf like the oat differ from that of a sedge-leaf?

15. What advantage to the oat or Indian-corn or timothy or other grass plant is it to have its *petiole* (that is its leaf-stem) in the form of a sheath?

16. (*a*) Observe the thin guard (the *ligule*) at the top of the sheath of the grass-leaf.

(*b*) Discover its use.

17. When an oat plant is bent or trodden down, where does it bend to straighten itself? (Perhaps the advanced pupils can discover how it accomplishes this bending at the joints or *nodes*.)

18. Observe how the oat-leaves in the field crop are adapted to securing the necessary amount of light and heat.

19. Why are windy situations favorable to grass crops, particularly those that bear grain, like wheat, barley and corn?

20. Point out the similarities and differences between oats and timothy or other grass plants:

(*a*) As to leaves.

(*b*) As to flowers.

(*c*) As to roots.

21. How does the stem of a grass plant differ from that of a sedge?

XXXV.—PLANTAIN—A WEED.

Collect a number of plaintain-seeds and sow them in a box. Observe the rapid growth of the young plants. Observations should also be made in waste-places and in the lawns of the neighborhood.

A. The Roots.

1. Dig up a number of the plants both from the box and lawns or waste-places.

2. (*a*) Describe the roots and infer why these plants are vigorous growers.

(*b*) Infer the effect of this vigorous growth upon the richness of the soil.

B. The Leaves.

3. (*a*) Describe a leaf.

(*b*) Where do the leaves grow upon the plant?

4. Discover the use of the threads that are easily observed by breaking the stem of the leaf (petiole).

5. What is their effect upon the grass and other plants overshadowed by them?

6. Give two reasons why a plantain is not a desirable plant to have growing in a lawn or garden.

Plants which are out of their proper places and so interfere with the growth of other plants are *weeds*.

7. Compare the effect of a plantain on a lawn with that of a dandelion.

C. The Flower and Fruit.

8. (*a*) Observe and describe the flowering-stem of a plantain.

A flower-cluster in which there are numerous sessile flowers arranged closely along an elongated axis is a *spike*.

(*b*) Name other plants which have their flowers in spikes.

9. What is the largest number of spikes you have observed on one plant?

10. Find the number of flowers on a spike and hence estimate the number on the plant.

11. How many seeds are in one seed-box?

The capsule or seed-box of the plantain is called a *pyxis*. The top comes off like a lid.

12. (*a*) Estimate the number of seeds produced by a vigorous plant.

(*b*) Compare the number of seeds produced by a plantain plant with the number produced by any other weed you know and infer which of these plants is likely to be the more common.

13. Investigate the causes which may prevent many of the seeds from becoming plants.

14. Use the lens to observe the seed and make enlarged drawings of the seed and seed-pod.

The different species of plantain are distinguishable by the form of the seed-pod, the form of the seed, and the number of seeds in a pod. Try to find as many different kinds as you can.

D. Its Extermination.

15. To prevent the growth of young plants, what precautions must be observed regarding old plants?

16. If young plants are prevented from growing, why will not the lawn become cleared of plantain?

Plants which live on year after year are said to be *perennial.*

17. Name other perennial plants.

18. What must be done with the old plants so as to exterminate this weed?

19. (*a*) In exterminating perennial plants with roots like those of the thistle and dandelion, and those with fibrous roots, what difference must be made in their treatment?

(*b*) What different conditions in the life of these plants necessitate a difference in the mode of their extermination?

E. Its Uses.

20. Discover, if possible, the uses of plantain.

XXXVI.—BREAD.

A. The Loaf.

1. (*a*) Observe bread at home; also, if convenient, at a store where it is sold, or at a bakery.

(*b*) Describe the different forms in which bread is made up.

2. Cut a slice off a loaf; name and describe the different parts seen.

3. (*a*) Examine the crust to discover the differences in the upper and under parts.

(*b*) Account for any differences you observe.

4. (*a*) Describe the interior of the loaf.

(*b*) In what respects does it differ from the crust?

5. To discover the cause of the spongy appearance of the loaf, perform the following experiments :—

(*a*) Place a small quantity of compressed yeast, or of home-made yeast, in a little flour mixed with tepid water so as to form a paste. Keep the whole in a moderately-warm place and observe the results. Describe what takes place.

(*b*) Put some yeast in a bottle containing a spoonful of syrup and ten or twelve spoonfuls of tepid water and observe the results.

(*c*) Masticate some grains of wheat or some bread a long time to note whether it tastes sweeter as a result of the chewing and mixing with saliva.

(*d*) Taste some wheat or other grain that is just beginning to germinate.

(*e*) With a compound microscope, observe the yeast plants obtained from some of the fluid in experiment (*b*).

The white part of the grain of wheat consists largely of starch. The starch is converted into sugar.

NOTE.—With proper apparatus, the advanced pupils can discover that the sugar in experiments (*a*) and (*b*) is converted into carbonic acid gas and alcohol by the little yeast plants.

6. Account for the swelling or rising of the mixture in (*a*).

7. What has become of the carbonic acid gas and alcohol before the bread comes out of the oven?

NOTE.—Yeast plants live upon or grow upon the sugary substances and give off carbonic acid gas and alcohol as waste products. The process is called *fermentation.*

8. Account for the spongy appearance of the interior of a loaf of bread.

9. Observe the interior to discover whether loaves are always of the same color.

B. Materials Used in Bread-Making.

10. Observe bread-making at home or in a bakery.

(*a*) Name the materials which are used.

(*b*) About what weight of each is used in making a four-pound loaf?

(*c*) Why does the loaf weigh less than the sum of its ingredients?

(*d*) Why is the loaf heavier than the flour required to make it?

(*e*) How many ounces of flour will make a four-pound loaf?

11. From what natural sources is flour obtained?

12. (*a*) Visit a mill in your vicinity to observe the process of making flour.

(*b*) Observe where flour is kept at home to preserve it in good condition.

13. (*a*) Cut a grain of wheat in two and examine the parts of which it is composed.

(*b*) Describe these parts.

(*c*) From what part of the grain is white flour obtained?

14. From your inspection of a grain of wheat, infer the difference between the flour used in making a loaf of white bread and that used in making a loaf of brown bread.

C. Processes of Bread-Making.

15. Observe bread-making at home or in a bakery.

(*a*) State in what order the materials are mixed.

(*b*) Describe minutely the successive processes through which the raw materials pass until the loaf is ready for the oven, noting carefully the time occupied in each.

16. At what temperature is the room in which the mixing is done?

17. (*a*) Prepare a mixture of flour and water as in experiment No. 5 (*a*) and put the same quantity in each of four glasses. To each add the same quantity of yeast and add a teaspoonful of salt to the fourth glass.

Set the first glass in a very hot place; the second and fourth glasses in a moderately-warm place and the third in a refrigerator or cold place. Observe the results and infer the effects of temperature on the growth of the yeast plant.

(*b*) From the results in glass number four infer the proper time to add the salt to the bread.

18. Account for the ingredients which are used being treated in a warm room.

19. Discover, if posssible, the temperature best suited for the preparation of the batter and also the dough.

20. What precautions are taken to preserve an even temperature in the batter?

21. What change takes place in the appearance of the batter before it is kneaded?

22. Place a piece of unkneaded dough in the oven and allow it to bake. From a comparison of this with

properly-prepared bread, infer the purpose of the kneading process.

23. Discover the effect of leaving the dough too long in rising.

24. (*a*) How are the loaves formed from the mass of dough?

(*b*) What determines the time at which the loaf should be placed in the oven?

25. Compare a baked loaf with one ready for the oven to determine what changes are produced by the cooking.

26. Discover the effect of the following on the bread:

(*a*) Too hot an oven.

(*b*) Too cool an oven.

27. Discover the average time of cooking a four-pound loaf.

28. It is recognized that the crust of well-baked bread is more easily digested than the inner part. From this, infer which is preferable:—

(*a*) A large loaf or a small one.

(*b*) The all-crusted or the partially-crusted loaf.

D. Properties of Bread.

29. What are the general properties of good bread:—

(*a*) As to the crust?

(*b*) As to the crumb?

(*c*) As to the odor?

XXXVII.—SUGAR.

A. Its Uses.

1. Place some sugar in a tumbler of water and stir. What has become of the sugar?

Sugar is said to be *soluble*.

2. Compare sugar with sand in respect to solubility in water.

3. Name other substances that are soluble in water.

4. How does the water taste after the sugar has been dissolved?

5. What two properties of sugar render it useful?

6. Name as many uses as you can to which sugar is put.

B. Kinds.

7. (*a*) Examine different kinds of sugar obtained at a grocery store.

(*b*) Describe them, showing in what points they resemble each other and in what points they differ.

8. (*a*) Taste raisins, dried currants, the pulp of the beet or banana, the sap of the maple and birch.

(*b*) How does each of these substances taste?

C. Sources and Manufacture.

9. Collect in the early spring some sap from the sugar maple. What is its color? Its taste?

10. (*a*) Place it in a kettle or dish over a hot fire and boil it. After boiling it for some time, note its quantity and compare this with the amount of sap at first placed in the dish.

(*b*) Account for this difference in volume.

11. (*a*) When the volume has been considerably diminished by evaporation, taste the liquid.

(*b*) How does the liquid now compare in sweetness with the sap when placed in the vessel?

(*c*) What is the color of the liquid now?

(*d*) How does the liquid now compare in density or thickness with the sap from which it has been formed?

(*e*) Let some of the liquid stand for a little time in a cup, then pour it off slowly and determine whether there is any sediment.

(*f*) When the liquid begins to thicken somewhat, pour the contents into a thick woollen bag held over a vessel to catch the drippings.

(*g*) Examine the liquid which passes through and determine what effect the straining process has had on the sediment and on the color.

Such a bag or strainer as this is called a *filter*, and this very sweet, thickish liquid is called *syrup*.

12. (*a*) Take a portion of this syrup and boil considerably longer. Set the remnant away to cool.

(*b*) What does it become? What is its color?

(*c*) Examine it carefully and describe its composition.

13. Discover whether you can get salt crystals from a salt solution as you have here obtained sugar crystals from the sap of the maple.

14. (*a*) Now, take some of the maple syrup and cause it to filter through a layer of animal charcoal (made from bones as the wood charcoal is made from wood).

(*b*) What is the color of the syrup as it filters through the charcoal?

This charcoal filtration is the method used in sugar refineries to clarify raw sugar.

15. If the time of the year or the place makes it difficult to get maple sap, you may perform similar experiments to those in Nos. 10 to 14 with a thin syrup made of brown sugar or granulated sugar.

16. (*a*) Let the clear syrup now boil until it becomes quite thick. Set away to cool in a cup or other vessel.

(*b*) What is formed? What is its color?

17. (*a*) Cut up the inner pulpy mass of stems of the sugar-cane if available. Boil the mass with water added. Then strain and otherwise treat as you did the sap of the maple.

(*b*) What products do you obtain?

The brown-colored, dampish sugar obtained before filtration through charcoal is called *raw sugar*, and the clarified product is called *refined sugar*.

18. Discover how the cubical masses of loaf sugar are formed.

That portion of the brown syrup that does not readily crystallize is allowed to drain off and forms *molasses*.

19. Suspend a string in a strong, warm solution of granulated sugar to observe crystals form along the thread as the syrup cools.

20. Do with the juice of the sugar-beet as you have done with that of the maple and sugar-cane, and note the products.

Nearly all the sugar of commerce is manufactured from sugar-cane or from the sugar-beet.

XXXVIII.—A CHAIR.

A. The Material.

1. Examine different chairs, noting the materials used in their manufacture.

2. What different kinds of woods are used in making chairs?

3. How is the wood as found in the tree prepared for the chair-maker?

4. Discover why particular kinds of wood are used in making chairs.

5. (*a*) Examine a common kitchen chair to discover the kind of wood used in making it.

(*b*) Why is this wood used?

B. The Legs.

6. (*a*) How many legs has it?

(*b*) Describe their shape.

7. Discover the reason for a chair's having four legs, rather than two or three.

8. (*a*) How are the four legs placed with reference to each other and to the seat?

(*b*) Why are they placed in this order?

9. How are they joined to the seat?

10. (*a*) Describe the bars connecting the legs.

(*b*) What is their shape?

(*c*) How are they joined to the legs?

(*d*) What is the use of these bars?

11. Examine other chairs to discover whether they have bars. If they have no bars try to discover the reason.

These bars are called *rails, rounds, or rungs.*

12. How is the strength of the chair affected by rails?

13. (*a*) Have all chairs legs of the same length?

(*b*) If not, what determines the length of the legs?

C. The Seat.

14. (*a*) Describe the part of the chair to which the legs are attached.

(*b*) What is its use?

(*c*) Note and describe different shapes of seats.

(*d*) Of what different materials are seats made?

(*e*) With what are seats sometimes covered?

(*f*) Examine the seat of a chair about to be recovered and describe what is under the covering.

D. The Back.

15. (*a*) Describe the remaining part of the chair.
(*b*) What is its use?
(*c*) Examine the backs of different chairs and describe any differences in shape and height you have noticed.
(*d*) In what different ways are the backs placed with regard to the seat?
(*e*) Which position is the most common?
(*f*) Why?

16. (*a*) Describe any other parts than those above mentioned which you have noticed on some chairs.
(*b*) What purpose is served by each of these?

17. (*a*) What other objects take the place of chairs?
(*b*) What is the main difference between each of these and a common chair?

18. Make a drawing of a common chair showing all the parts.

XXXIX.—A RIVER VALLEY.

1. Observe the effect of rain:—
(*a*) When falling on a nearly level area.
(*b*) When falling on a hill.

2. In each case, what evidence is there that rain can alter the form of the land?

3. Observe in what kind of soil the deepest runnels are made by the streams of water.

4. What becomes of the earth and stones washed away by the water?

5. What kinds of materials are carried farthest by the water? What kinds are carried the shortest distances?

6. If the stream opens into a pool or pond or lake, observe what kinds of materials are deposited near the mouth of the stream and what kinds are carried into the deeper parts of the water.

See experiment under Soil, page 154.

7. (*a*) Account for the deposition of coarse gravel, fine gravel, sand and silt, where you find them in a stream or pond.

(*b*) Where has each of these classes of material come from?

8. Observe how each successive rainstorm deepens and widens the bed where the water flows.

9. After every rainstorm, why are the streams of water muddy?

If the stream is a permanent one and large it is called a *river;* the bed wherein the water flows is its *channel;* the land on both sides which confines the water to its channel are the *banks;* and the country through which the stream flows is a *valley.*

10. (*a*) Observe how the river makes its way through the valley.

(*b*) In what part of its course does the water flow most rapidly?

(*c*) Where most slowly?

(*d*) Upon what does the velocity of a stream depend?

(*e*) In which part is the water deepest?

(*f*) In which part most shallow?

(*g*) What connection is there between the rate of flowing and the depth of the water?

11. Is the stream always of the same width? Account for any differences in width.

12. (*a*) Where are the banks being worn away and where does deposition of materials take place?

(*b*) Why do these changes occur at these particular places?

The wearing away of soil or rock by the influence of water and ice is *erosion*.

13. What causes determine whether erosion or deposition shall take place?

14. (*a*) Compare the points of erosion and deposition when the stream is at its ordinary height with similar points when the stream is at its flood height.

(*b*) Are these points always the same? Why?

(*c*) Compare the amount of erosion by swift and slow streams.

15. (*a*) Are there any pebbles or stones in the channel that do not belong to the rocks of the district where they are found?

(*b*) Where have they come from and through what agency?

(*c*) What is their shape?

(*d*) Account for this shape?

16. Examine the valley to determine whether the stream has changed the location of its bed.

17. (*a*) What determines the direction of the stream?

(*b*) Account as far as possible for the bends in its course.

18. (*a*) At a bend in the river, on which side is the water the deeper?

(*b*) Account for the shallow water on one side and the deep water on the other.

(*c*) On which side of the bend is erosion taking place most rapidly?

19. How does a stream tend to straighten its course?

20. (*a*) In which part of the valley has the river its course?

(*b*) Account for the level stretches in the valley.

21. (*a*) Examine any falls or rapids in the stream.

(*b*) What determines whether there shall be falls or rapids?

22. (*a*) In what direction relative to the stream are the falls gradually moving?

(*b*) Why?

23. (*a*) If possible, examine the sides of the valley.

(*b*) Describe them.

24. What causes determine whether there is a gradual slope or a bluff?

25. What forces are at work tending to obliterate the traces of the action of the river as you go back from the river bed?

26. (*a*) Observe any small streams that flow into the river.

(*b*) In what direction do their courses lie with reference to that of the river?

27. (*a*) Examine the river where a tributary enters it.

(*b*) Are there any deltas or bar formations? Account for their presence or absence.

28. What effect have tributaries upon the course of a stream?

29. How does vegetation on the banks affect the character of a stream?

30. How do animals like beavers and muskrats affect the river?

31. (*a*) How has man modified rivers in certain places to serve his purposes?

(*b*) What industries are assisted by the currents of rivers?

XL.—A SCHOOL GARDEN.

A school garden may be made of any convenient or suitable size.

It may be situated in a part of the school grounds or it may be a plot bought or rented outside of the school site, but convenient to it.

Whether in or outside the school site proper it should be fenced or protected from careless or accidental invasion.

It may be separated into different plots for each class if there is enough land, in which case the older pupils will undertake more difficult problems than the juniors. If the space be only a square rod or two the pupils will all have to work together.

School gardens will and should be different in different school sections, and will in the same section vary to some extent, especially in the plots devoted to annuals, from year to year.

Training vines over the porch, woodshed or summer house, planting ornamental trees and shrubs in suitable places around the grounds, cultivating flower plots near the front door or flower borders along the walks, are to be considered as part of the work of school-gardening.

Some of the practical problems that may be attempted to be studied by the aid of the garden, are:

(*a*) Cultivation, fertilization and drainage of the soil.

(*b*) Weeds and weeding.

(*c*) Slipping, layering, budding and grafting.

(*d*) Artificial pollination, starting or improving varieties.

(*e*) Rotation of crops.

(*f*) Learning the appearance and testing the hardiness, etc., of plants or varieties of plants not generally known in the neighborhood.

(*g*) Experimenting upon the cultivation of wild flowers and wild fruits.

(*h*) Identification and remedial treatment of insect and fungal enemies of plants.

Let us try to hasten the time when every pupil will have his own division of the school garden in addition to the general one. Every child who can have a little plot for a garden of his own at home should enter at once upon its possession and cultivation. A child cannot find a pleasanter, happier or more profitable way of spending his leisure than in attending to his own little garden.

The plot on the following page is 28 ft. by 42 ft.; scale, 8 ft. to the inch. A, B, C, D are four fields to illustrate rotation of crops every cycle of four years. A is wheat; B, meadow of timothy and clover (sown with the wheat); C, meadow, broken up in the fall; D, corn or root crop, sown in the fall, if crop is off in time, with fall wheat.

E, F and G show a rotation for a stock farm. E is oats and pease followed by rape in the fall; F is oats followed by rye in the fall; G is the rye turned down in the beginning of summer and followed by fodder corn.

Turnips follow lettuce and spinach follows radish in the same year.

1. Criticise the size, plan and contents of this plot with reference to suitability for your school.

Spiræa.	Rose or Pyrus.	Weigelia or Deutzia.	Hydrangea or Cytisus.
Red Currant.	Goose-berry.	Black-berry.	Red Raspberry.
Black Currant.	White Currant.	Blackcap.	Straw-berry.

Meadow Fescue.	Satin Grass.
Awnless Brome Grass.	Orchard Grass.
Wheat.	Rye.
Barley.	Oats.

Tomatoes.	Potatoes.
Beans.	Pease.
Beets.	Parsnips.
Lettuce. Turnips.	Radish. Spinach.

A
followed successively by
B C D.

B
followed successively by
C D A.

C
followed successively by
D A B.

D
followed successively by
A B C.

E
followed successively by
F G.

F
followed successively by
G E.

G
followed successively by
E F.

Verbena.	Petunia.
Aster.	Zinnia.
Phlox.	Salpiglossis.
Mignonette.	Scabiosa.
Pansy.	Sweet Pea.

2. If this plan is suitable so far as it goes, how would you use an additional strip of eight or ten feet on the side?

3. Draw a plan of your school grounds and on it mark places where you would plant particular trees and shrubs. Give reasons for your selection.

NOTE.—All the forms of the cabbage group—cabbage, broccoli, brussels sprouts, kale and cauliflower might occupy a division. A dozen small plots of as many perennial flowers, rows of cuttings and slips from various kinds of cultivated and wild plants, specimens of the corn family with the varieties—are examples of the uses to which additional divisions might be applied.

The cut on the previous page represents the Broadview Boys' Institute, Toronto. The plot of land is laid out into twenty-seven farms, each forty feet by twenty feet, with walks between them. Two boys manage each farm. The boys provide their own seeds and plant such things as they choose. The twenty-seven farms form a township, the affairs of which are managed by a reeve and five councillors, elected by the fifty-four "farmers." The farms are named on the crosses seen in the cut. The two boys who manage each plot select its name. Some of these are Lake View Farm, Maple Leaf Farm, The Riverside Farm, Thornhill Farm, Shore Acres Farm, Homestead Farm, etc. A fall fair, managed by the boys themselves, is held, when due recognition is paid to the best "farmers."

XLI.—SOIL.

1. After clearing off the grass, if any, make a nearly-square hole, like a fence-post hole, about two feet deep. Pare one or more sides with a sharp spade, so as to show a clean, perpendicular surface. Make exact records of the color and depth of the soil and the color of the subsoil.

The surface of the earth more or less finely broken up is the *soil*.

The part beneath the soil is the *subsoil*.

2. Repeat this operation in different places; *e.g.*, in the school-yard near the school-house, in a corner of the school-yard, on the roadside, in a cultivated field near the school grounds, in the woods or other situation where the soil has never been cultivated.

3. (*a*) Compare variations, if any, in color and depth of soil and color of subsoil in the different excavations made.

(*b*) Account as far as possible for each variation noted.

4. Of what is the surface layer in the forest composed?

The dark surface matter found in woods and formed of decaying vegetation is *organic matter*.

The part of the soil resulting from the decomposition of rocks is *inorganic matter*.

The organic matter, whether of vegetable or animal origin, in a soil is called *humus*.

5. (*a*) At a selected excavation, carefully take off about a peck of the soil, cutting from the surface straight down to the subsoil.

(*b*) By hand or with a trowel, break up and thoroughly stir and mix the soil on a board to obtain a true sample.

(*c*) Weigh out a pound and spread it out thin on a board or sheet of paper. Put it in a drying-place for twelve hours or longer, occasionally stirring it to "air-dry" it.

6. (*a*) Weigh the dried soil.

(*b*) Compare with the weight before drying.

(*c*) Observe any change in color.

(*d*) State your conclusions.

7. (*a*) Place the air-dried soil on a flat shovel or spread it in a pan and put on a stove, or in a hot oven for three or four hours to "kiln-dry" it.

(*b*) Weigh again and compare as before.

8. Return the kiln-dried soil to the shovel and put it on the fire—not on the stove. When it has burned and smouldered until it ceases to smoke remove, cool, and

weigh it. From this determine the quantity and proportion of inorganic matter in the soil.

9. Determine the properties and proportion of the organic matter in the soil as outlined in the lesson on "Clay and Sand."

10. (*a*) From the soil as mixed in No. 5, take enough to fill one-third of a tall, wide-mouthed glass vessel. Fill the vessel nearly full with water. Stir thoroughly and shake. Set the vessel aside to settle.

(*b*) Observe the material floating on the water and the layers forming the sediment.

(*c*) Investigate the nature of the "scum."

(*d*) Syphon off the water. Obtain samples from the upper, middle and lowest layers of the sediment. Dry each and examine to find differences in color and texture.

11. (*a*) Infer the effects of heavy rains upon soils.

(*b*) Infer differences between hill-side soils and adjacent-valley soils.

12. (*a*) Take a sample from the lower layers and while stirring it allow water to run over it until the water runs off clear.

(*b*) Describe the earth remaining.

(*c*) What constituents have you found in the soil you have examined?

XLII.—CLAY AND SAND.

1. (*a*) Moisten some sand and clay. Form two sets of objects, as balls, cubes and cups, one from the sand and the other from the clay. Place these in the sun or near the stove and observe the effect of drying.

(*b*) Which substance retains its form?

(*c*) Which is the more adhesive sand or clay?

2. (*a*) Fill two filters, one with sand, the other with clay, hollowed so as to form a cup. Gently introduce water into each.

(*b*) Through which substance does water pass most readily?

(*c*) Observe whether all parts of the surface of the ground dries equally fast after rain.

(*d*) Examine the soil where the ground dries most readily and describe it.

(*e*) Examine the soil where the ground dries slowly and describe this soil.

3. (*a*) Have several flower-pots of the same size and shape. Dry several kinds of soil, as gravel, sand, clay and garden loam. Place an equal weight of each soil in the pots. Suspend one from a common spring balance and notice the weight registered. Now, slowly pour water upon the soil until it is thoroughly saturated and cover the mouth of the pot with a piece of oiled cloth or oiled paper. Allow the water to drain until no more will flow away. Compare the weight of each pot before soaking with that after all the water has drained away.

(*b*) Which soil has increased the most in weight?

(*c*) Which has increased the least?

(*d*) To what is the increase of weight due?

(*e*) Which kind of soil will best resist heat and drought?

(*f*) Which kind will be best for wet weather?

4. (*a*) Again, take four ordinary lamp chimneys and tie a piece of cotton cloth over the bottom of each. Place equal weights of well-dried soil in each, as in the last experiment. Set the four chimneys at the same time in a vessel having about an inch of water in it.

(*b*) Describe what happens.

(*c*) In which vessel does the water rise most rapidly?

(*d*) After a few minutes weigh each chimney.

(*e*) Which has increased most in weight?

(*f*) Which has increased the least?

(*g*) Compare these increases in weight with those in the last experiment.

(*h*) What kind of soil would be best for plants in dry weather?

(*i*) In wet weather?

5. Why is it easier to walk or drive on a sandy road immediately after rain than before it?

6. Why does moist clay adhere to one's boots?

7. Why is a clay soil called "heavy" and a sandy one "light"?

8. (*a*) Put an equal quantity of sand and of clay into similar dishes and place on a stove.

(*b*) Observe which heats more rapidly.

(*c*) Remove from the stove and observe which retains its heat longer.

(*d*) Infer with reasons the soils that can be tilled earliest in the spring, and the soils in which seeds will germinate most quickly.

(*e*) State the reasons in each case.

9. (*a*) Keep a portion of the garden well hoed during dry weather to observe the effect upon the growing plants.

(*b*) Which part, the well-hoed or the other part, seems to retain moisture better?

(*c*) By examining dusty places like roadsides and nearby hard ground during very dry weather, determine a way of preventing evaporation from the soil.

XLIII.—ICE AND MICA.

1. In what respects are ice and mica different from all animals and plants that you have seen?

2. Report observation upon the source of each of these two minerals.

3. Are they solid or liquid?

4. Which is the more glittering or shining?

The quality of the surface of a mineral with regard to the kind and intensity of the light it reflects is its *lustre*.

A surface which has lustre is said to be *lustrous*.

5. Scratch each with a knife or wire nail. Note differences in the streaks made.

6. Compare the color of ice and mica.

7. Which is more transparent?

8. Try to scratch mica with ice and ice with mica, and from this infer which is harder.

9. Try to break each, and infer which is more brittle.

10. If possible bend each, and judge which is more flexible.

11. By bending, twisting or altering the shape in any way, ascertain which returns to its original form more readily and more completely, and infer which is the more elastic.

12. Note the difference in the way in which they split.

The tendency of a mineral to separate parallel to certain planes is *cleavage*.

13. Place both in water to find out which is heavier.

14. Apply heat to each, and infer which can be melted more easily.

15. From the qualities you have tested infer the uses of each.

XLIV.—LIMESTONE.

A lens and hammer are needed for work connected with rocks and minerals.

This stone is widely distributed in Canada, and may be found almost everywhere in southern Ontario, either as boulders in the fields or in "place" along some stream, lake shore, or in some quarry.

1. If a limestone quarry is in the neighborhood, visit it and observe the manner in which the stone admits of being readily taken out.

This condition of layer on layer is called *stratification* and each layer is called a *stratum*.

2. Observe whether the strata are horizontal or not.

When not horizontal, the angle of inclination of the strata to the horizon is their *dip*.

3. Observe the markings on the rocks to discover any remains resembling shells.

These remains are called *fossils*.

Observe whether the strata are continuous or if they are fractured.

If the strata are fractured, observe whether the opposite sides of the break have been displaced.

The displacement of the layers on one side of a fracture is called a *fault*.

4. Can you scratch limestone with your finger-nail?

5. (*a*) Draw the point of a pocket-knife forcibly over a piece of limestone. Does the knife scratch the stone?

(*b*) From this infer which is harder, limestone or steel.

6. (*a*) Examine the specimens to discover fossils. Compare, if possible, with similar forms now living. Are they shells, corals, trilobites, etc.? Describe the fossils found. Compare them with any living animals of similar form that you may have found. In what situations have you seen such living forms?

(*b*) Infer whether limestone was formed under water.

7. If these rocks were formed beneath the sea, what changes must have taken place in the level of the land?

8. Examine a piece of limestone with a lens. Describe its appearance. Are there any crystals in it?

9. (*a*) Weigh a piece of limestone, then place it in a fire till it is red hot.

(*b*) As soon as it is cold, weigh it again and note the difference in weight.

(*c*) What change has taken place in the limestone?

The part of the limestone which remains after it is roasted is *quicklime.*

10. (*a*) Wet the quicklime with a little water and describe what happens. Note the change of temperature.

(*b*) Take a little sulphuric acid and add its own bulk of water to it. Note what happens. Why?

(*c*) What causes the rise in temperature when water is added to the quicklime?

11. Put a piece of red litmus-paper on moist limestone and then on the moistened quicklime. What happens in each case?

When quicklime is treated with water until it will absorb no more, it becomes *slacked-lime.*

12. (*a*) Where have you seen slacked-lime used?

(*b*) What use was being made of it?

13. Have you ever seen limestone burnt on a large scale? If so, describe the process.

The furnace in which limestone is roasted into quicklime is a *lime-kiln.*

14. What use is made of unburnt limestone?

15. (*a*) If there are any limy springs in the neighborhood observe them to discover if limestone is now being formed.

Travertine, "petrified moss," is formed by such springs in most parts of southern Ontario.

(*b*) Describe the appearance of such limestone.

(*c*) Compare it with the old limestone.

(*d*) Discover whether there are similar fossils in it.

(*e*) Discover if it will burn into quicklime.

XLV.—GOLD-BEARING QUARTZ.

1. Describe the appearance of quartz.

2. What does quartz closely resemble in appearance?

3. (*a*) Try to scratch it with your knife and then try to scratch the knife with the quartz.

(*b*) Infer from this which is the harder of the two.

4. (*a*) Try a similar experiment with a piece of glass and quartz.

(*b*) Again, infer which is harder, glass or quartz.

5. (*a*) Break a piece of quartz into fine particles; compare these with sand.

(*b*) Infer from what kind of rock sand is formed.

(*c*) Compare also with the sand on coarse sandpaper.

6. Why is sandpaper useful?

7. Heat quartz red hot and cool it. Discover whether it will slake like limestone.

8. Strike a piece of quartz against steel and discover what happens.

9. Examine a piece of gold-bearing quartz to discover other minerals than the quartz.

Such generally has gold and iron pyrites.

10. What is the color of each of these?

11. Discover which is harder, your knife or iron pyrites.

12. Discover which is harder, quartz or iron pyrites.

13. Powder and strongly heat some iron pyrites. Describe what happens.

14. (*a*) Observe the smell while the pyrites is being roasted and infer what substance is being given off.

(*b*) Describe the material left and note its color.

(*c*) What has passed off from the pyrites?

(*d*) Why is the powder that is left rusty?

15. Try to cut a piece of gold with a knife and to flatten it with a hammer.

A metal which can be beaten or rolled out without breaking at the margin is said to be *malleable* and possesses the property of *malleability*.

16. Compare gold and iron pyrites as to hardness and malleability.

17. Heat gold and compare its smell then with that of iron pyrites when heated.

18. Select pieces of quartz, pyrites and gold of nearly equal size and discover which is heaviest and which is lightest.

19. Weigh a bit of quartz, first in air, then tied by a hair to the beam of the balance in a glass of water. Subtract the weight in water from that in air. Divide the weight in air by the difference between the two former weights. The quotient will be the weight of the

quartz as compared with that of an equal volume of water.

The weight of a substance as compared with an equal volume of water is its *specific gravity*.

20. In a similar way determine the specific gravity of iron pyrites, and, if there is gold enough for the purpose, also of gold.

21. (*a*) Compare the specific gravities of gold, iron pyrites and quartz.

(*b*) Infer from this why gold is found in the layer of sand resting on the rock in the beds of creeks in some gold-mining regions.

XLVI.—MINERALS.

Observations on minerals may be begun by comparison of the qualities of two or more common species; for example, water and clay, clay and chalk, mica and anthracite, mica and limestone, limestone and copper, limestone and quartz.

A cabinet of standard specimens for comparative determinations of lustre and hardness is desirable, and, although not indispensable for the purposes of nature-study, it is necessary for even elementary study of mineralogy.

The extent to which a study of minerals may be carried in a school will depend on its equipment for heating, crushing, weighing and otherwise manipulating the specimens.

Having studied the minerals mentioned in Lessons XLIII and XLIV, other minerals should be examined and as many of the following points noted as possible:—

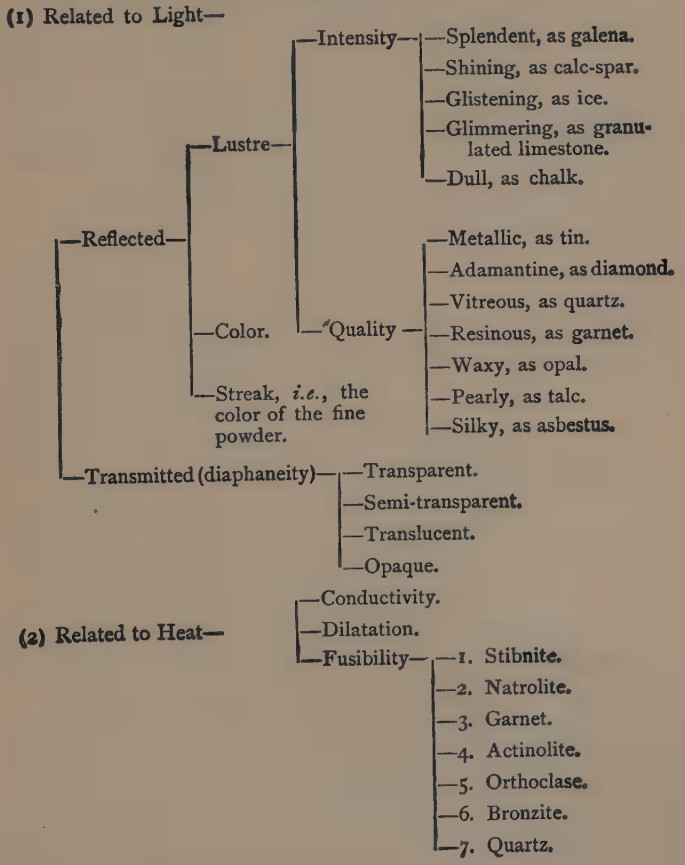
(*a*) The sources and uses of minerals.

(*b*) Their condition, whether solid, liquid or gaseous.

(*c*) Their form, whether massive or crystalline.

(*d*) Their chemical composition.

(*e*) Their physical properties :—



(3) Related to Electricity—Some minerals are affected by a magnet, usually in the proportion of their iron. Apply the magnet to the pulverized mineral. Rub the mineral on silk or woollen cloth and discover whether it will immediately afterwards attract or repel pith or bits of paper:

(4) Related to Cohesion—(*a*) Hardness—
- 1. Talc.
- 2. Gypsum.
- 2½. Mica.
- 3. Calcite.
- 4. Fluorspar.
- 5. Apatite.
- 6. Feldspar or orthoclase.
- 7. Quartz.
- 8. Topaz.
- 9. Sapphire.
- 10. Diamond.

NOTE.—1 to 2½ can be scratched by the finger-nail; up to 3 by copper; up to 5 by glass; up to 7 by a knife-blade.

(*b*) Tenacity—
- Brittle.
- Sectile.
- Malleable.
- Flexible.
- Elastic.

(5) Related to Cleavage if crystalline—
- Basal.
- Cubical.
- Lateral.
- Octohedral.
- Rhombohedral.
- Diagonal.
- Prismatic.

(6) Related to Fracture—
- Conchoidal.
- Even.
- Rough.

(*f*) Their specific gravity. See Lesson XLV, No. 19.

(*g*) Their solubility. Frequently it is important to note the action of the pulverized mineral in hot hydrochloric acid.

(*h*) The manner of extracting a particular mineral from the earth.

(*i*) *Taste.*—Some minerals like common salt are soluble in water. These usually have a distinct taste—saline, astringent, bitter, pungent or acid.

(*j*) *Odor.*—Many minerals on heating give off characteristic odors—sulphurous, or that of garlic, or of decaying horse-radish, or of rotten eggs, or of prussic acid.

Minerals fall into two great subdivisions:—

(*a*) Metals.

(*b*) Non-metals.

All true metals have metallic lustre and are opaque in the thinnest sections.

The chief metals in Canada are gold, silver, platinum, lead, copper, nickel and iron.

The chief non-metals are coal, asbestus, mica, clay, petroleum, natural gas, building-stone, arsenic, salt, and apatite.

XLVII.—TEMPERATURE.

Procure the following:—

(*a*) Four beakers (tumblers) of water at temperatures of approximately 60° C. (140° F.), 30° C. (86° F.), 10° C. (50° F.) and 0° C. (32° F.), respectively.

(*b*) A small quantity of water, say 60 grams (one-fourth of a tea-cup), at boiling point. A much larger quantity, 600 grams (3 tea-cupfuls), at 40° C. (104° F.) and a piece of ice.

(*c*) A thermometer.

(*d*) A Bunsen burner or a spirit lamp or a hot stove.

A. Meaning of Term "Temperature" and Distinction From Quantity of Heat.

1. (*a*) Having prepared the four beakers with contents named in No. (*a*), thrust a finger into the first beaker.

(*b*) Describe the condition of the water.

(*c*) Thrust a finger into the fourth beaker.

(*d*) Describe the condition of the water.

(*e*) State the difference in condition between the two quantities of water.

2. Now, test similarly the second and third beakers of water.

3. Which water has the greater degree of heat, that in the second beaker or that in the third?

4. State the general results of your observations with reference to the degrees of heat of the water in the different beakers.

The degree of heat which is possessed by a substance is its *temperature.*

5. (*a*) Require the pupils to touch the ice.

(*b*) What is the nature of its temperature?

6. Compare the temperature of ice with that of the Bunsen flame or hot stove.

The hot stove or the Bunsen flame is said to be of a *high temperature,* while the ice has a *low temperature.*

7. (*a*) Touch or feel bodies of different temperatures, as air issuing from the register, air coming through an open window, the door-knob, a slate, the blackboard, and state what you know of their temperature.

(*b*) Examine the contents of the beakers described in No. (*b*).

(*c*) Which water is at the higher temperature?

(*d*) Place equal pieces of ice in the two beakers.

(*e*) Compare what takes place in the one with what takes place in the other.

(*f*) What causes the ice to melt?

(*g*) Which quantity of water produced most melting?

(*h*) Which, therefore, possessed the greater quantity of heat?

8. Does temperature mean the same as quantity of heat?

9. (*a*) Place a piece of ice of the same size as in No. 7 (*d*) in a beaker containing 1,200 grams of water at 40° C. (104° F.).

(*b*) Compare the result with that observed in the experiment with water of the same temperature used in No. 7 (*d*).

10. Upon what does the quantity of heat of a body depend?

11. What is the difference between the temperature of a body and its quantity of heat?

B. The Sense of Touch Cannot be Relied Upon to Give us Accurate Information with Regard to Temperature.

12. (*a*) Prepare three beakers, or cups, of water, A, B and C. Make A as hot as you can bear to hold your fingers in; make B of the temperature of your hand, so that it will feel neither hot nor cold, and make C very cold by putting ice into it.

(*b*) Place a finger of one hand in A and a finger of the other hand in C. Continue to hold them there for a minute, then withdraw and thrust them into B. How does the water in B now feel to the finger taken from A? To that taken from C?

(*c*) Compare the temperatures of the finger immediately before and immediately after being placed in A.

(*d*) Compare similarly the temperatures of the finger placed in C.

(*e*) Compare the temperatures of the fingers immediately before being placed in B.

(*f*) What caused the difference in the sensations in the two fingers when placed in B?

(*g*) Is the water in B hot or cold?

13. Make other observations, as:—

(*a*) Determine, by touch, the comparative temperatures of different articles subjected to the same temperatures for some time; *e.g.*, the iron head of a hammer and its wooden handle, the slate and its frame, an iron inkstand and a lead pencil beside it, a piece of oilcloth and a piece of carpet on the same floor—each of the above pairs of articles when lying in the heat of the sun in summer.

(*b*) Infer whether touch is an accurate test of the temperature of a body.

C. The Thermometer is Used in the Accurate Determination of Temperature.

Since the thermometer with Fahrenheit markings is more generally used for domestic purposes, it is more appropriate for use in these experiments. In a lesson

on the thermometer, the centigrade may be introduced and its markings compared with those of the Fahrenheit.

14. (*a*) Thrust the thermometer into cold water.
(*b*) How does the column of mercury act?
(*c*) Now, thrust it into hot water.
(*d*) How does the mercury act?
(*e*) Hold the bulb against a piece of ice.
(*f*) Compare the observation with that in the first case.
(*g*) Hold the bulb near a flame.
(*h*) Compare the effect with that in the second experiment.

15. State how the mercury column acts under the influence of high and low temperatures.

16. (*a*) Place the thermometer in contact with substances of different temperatures.
(*b*) Note the height of the column in each case.

17. From your observations, state the relation between the change in the mercury column and the change in the temperature.

18. Find the temperature of different objects, as—different beakers of water, ice, the atmosphere of the room, the hand, etc.

19. Exercises for further observation: Determine:
(*a*) At what temperature water freezes.
(*b*) At what temperature water boils.
(*c*) At what temperature the room is kept.
(*d*) The temperature of the body.
(*e*) How temperature is affected by evaporation.
(*f*) How temperature is affected by sudden meltings—mixture of snow and salt.

NOTE.—Carefully fill in that portion of your weather-chart relating to the temperature of the atmosphere.

XLVIII.—CONDUCTION.

1. (*a*) Place one end of a piece of iron wire, six or eight inches long, in the flame of a lamp or of a stove; hold the other end in the hand.
   (*b*) What change takes place in the wire?
   (*c*) How do you know?
   (*d*) How is the temperature of the wire affected?
   (*e*) What caused this change of temperature?
   (*f*) What is the source of the heat?
   (*g*) How has the heat got from this source to the hand?

The heat is said to have been transmitted from the flame to the hand along the wire by *conduction*, and the wire is called a *conductor*.

2. (*a*) Test similarly pieces of copper wire, wood, slate-pencil and glass.
   (*b*) Which of these substances is the best conductor? Which the poorest?
   (*c*) Which would be the better material for the handle of an oven door, iron or glass or wood? Give reasons for your answer.
   (*d*) Why is wood sometimes used to make part of tea-pot handles?

3. Examine the handles of such articles as tea-kettles, lid-lifters, coffee-pots, to discover how the conduction of heat to the hand is prevented.

4. (*a*) Take a test-tube nearly filled with water. Hold it in an inclined position with the upper surface directly over the flame of a lamp.
   (*b*) After a short time, what takes place?
   (*c*) When the water is boiling, what must be the temperature of the water at the mouth of the tube?

(*d*) What is the condition of the temperature of the water in the lower portion of the tube?

(*e*) What can you infer concerning water as a heat conductor?

5. Compare water with iron or copper in respect to conduction of heat.

Liquids are generally much poorer conductors than solids.

XLIX.—CONVECTION.

1. (*a*) Place a test-tube containing water, with a few very small particles of coloring matter or scrapings from a piece of rotten, water-soaked wood at its bottom, over the flame of a lamp. Hold the test-tube by a wire. Observe what takes place in the particles at the bottom of the tube as soon as heat is applied.

(*b*) Describe fully this movement.

2. (*a*) Compare the temperature of the water at the bottom of the tube after heat has been applied a few seconds with the temperature of the water in the upper portion of the tube.

(*b*) Infer what becomes of the water at the bottom when it is heated.

3. Continue the heating. How does the water at the top of the tube become heated?

4. (*a*) Take a wide-bottomed beaker, place small particles of matter in the bottom of the beaker as in the above experiment, and fill with water. Apply the flame of the lamp to the bottom near the edge and observe what takes place.

(*b*) Describe the currents of water as indicated by the motion of the particles.

(*c*) In what directions do they move?

5. (*a*) Place a cork under the surface of water and release it. What becomes of it?

(*b*) Why does it rise?

(*c*) From this infer why the heated water rises in the test-tube and beaker.

In these cases the mass of water is said to be heated by *convection*, and the currents you observed are called *convection currents*.

6. Describe how a mass of water is heated from below.

7. Observe the direction of the sparks and smoke from a bonfire on a calm evening.

8. (*a*) Let loose a small piece of paper a few feet from the bottom of the bonfire or near the open draft of a stove.

(*b*) What becomes of it? In what direction did it move?

(*c*) What caused it to move in this direction?

9. (*a*) Compare the temperature of your back with that of your front while standing near and facing the bonfire.

(*b*) Why is this the case?

(*c*) Infer the direction of the currents of air and their comparative temperatures.

These currents in air are also called *convection currents*.

10. In which part of a closed, heated room will the air be at the highest temperature? Why?

11. (*a*) Let loose a small piece of paper at the mouth of a grate in which there is a bright fire.

(*b*) What becomes of the paper? Why?

(*c*) Explain why there is a draft up the chimney while the fire burns.

12. (*a*) Test the drafts made by letting down the upper window sash a little and raising the lower sash to the same extent, during a cold day and while the air in the room is warm.

(*b*) Describe the direction of these currents.

(*c*) Compare the temperatures of the in-coming and out-going currents.

(*d*) Which current goes through the upper sash?

(*e*) Account for the hot air taking the course that it does.

L.—EVAPORATION.

1. (*a*) Place a small quantity of water in a saucer and leave it exposed and observe what takes place.

(*b*) What has become of the water?

(*c*) Where is it now?

(*d*) What caused it to disappear?

2. (*a*) Observe the wooden roofs of buildings when the sun shines strongly on them after a shower.

(*b*) What do you notice?

The moisture in the air is called *vapor* and the process by which the water is slowly changed into vapor is called *evaporation.*

3. Where else have you noticed evaporation taking place?

4. (*a*) Why are wet clothes hung on a line?

(*b*) What becomes of the water?

5. Why are wet clothes sometimes placed near the stove?

6. How does increase in temperature affect the rate of evaporation?

7. When does the dew on the grass disappear? Why then?

8. Since the water in the saucer disappeared into the atmosphere what becomes of part of the water of our rivers, lakes, swamps, and seas?

9. Place a wet saucer outside in the winter time. After some time, observe whether it is dry or not.

10. (*a*) Observe patches of snow in the fields during cold yet stormless winter weather.

(*b*) How do the patches now compare in size with the same when first observed?

(*c*) What caused the difference?

11. Try to discover whether ice always melts before evaporation.

12. Where does all the vapor from these sources go?

13. (*a*) Place over a flame a test-tube half filled with water and fitted with a cork, through which is inserted a piece of glass-tubing, its lower end being above the surface of the water.

(*b*) What takes place almost immediately after the application of the heat?

(*c*) What caused these to rise?

(*d*) Describe the condition of the water while boiling is taking place.

(*e*) How do the bubbles now seen compare in size and action with the bubbles first observed?

(*f*) Observe the bubbles bursting and determine what they contain.

(*g*) What do you observe issuing from the glass-tubing?

(*h*) Observe carefully where it is first visible.

(*i*) Do you see the vapor at the mouth of the tubing?

(*j*) Do you see it in the test-tube?

(*k*) How far is the point where you first see it from the end of the tube?

14. (*a*) What must be above the water in the test-tube and issuing from the end of the tubing?

(*b*) What is the nature of its temperature?

(*c*) How does it compare in temperature with the vapor rising from a wet roof, or from an exposed saucer containing water?

This invisible, highly-heated vapor is called *steam*, and this violent process by which the steam is produced is called *boiling*.

LI.—CONDENSATION.

1. (*a*) Hold a slate close to the mouth of a tube while the water which it contains is boiling.

(*b*) What do you observe on the slate?

(*c*) Where does it come from?

2. Compare the temperature of the slate with that of the steam.

3. How is the temperature of the vapor affected by contact with the slate?

4. What change was effected in the steam by its contact with the slate?

5. Compare the temperature of the steam issuing from the tube with that of the air of the room.

6. What effect upon the temperature of the vapor has its contact with the air?

7. What was the visible effect of this lowering of the temperature of the vapor?

8. (*a*) Place a pitcher or tumbler of cold water in a warm room.

(*b*) What do you notice on the outside of the vessel?

(*c*) Where has it come from?

9. In what form did the moisture exist in the air?

10. Compare the temperature of the glass with that of the atmosphere and its vapor.

11. What effect on the vapor of the atmosphere had its contact with the cold vessel?

12. How is the condition of invisible vapor affected by its contact with a body of much lower temperature?

This change in its condition is called *condensation.*

13. Under what circumstances is vapor condensed?

14. (*a*) Breathe against a cold slate.

(*b*) Explain the effect produced on the surface of the slate.

15. (*a*) Why is the breath visible on a cold morning?

(*b*) Why is it not visible on a warm morning?

16. Explain why windows in cold weather are clouded with moisture.

17. On which side of the window-pane is the moisture found? Why?

18. (*a*) In the experiment on boiling, Lesson L, No. 13, place the flame of the lamp close under where the vapor first becomes visible.

(*b*) What effect is produced?

(*c*) What caused this effect?

(*d*) How far from the tube can you see the vapor?

(*e*) What becomes of it after this point?

LII.—FOG, MIST AND CLOUDS.

1. (*a*) What becomes of all the vapor constantly forming on the earth?

(*b*) Does it all remain invisible?

2. Make observations in the morning and evening along a river bank, in a marshy place, in a low valley, and state the results of your observations.

3. Why was the vapor seen in the places you were directed to observe rather than at other places?

4. (*a*) Why was it seen at those particular times of the day?

(*b*) What was the condition of the atmosphere?

5. When and why did it disappear?

When vapor is condensed and floats very close to the surface of the earth it is called *fog* or *mist*.

6. When or where else have you seen such fleecy forms of vapor?

When the condensed vapor is visible in great masses high up in the atmosphere such masses are called *clouds*.

7. (*a*) Under what conditions is the invisible vapor of the air condensed?

(*b*) Infer the origin of clouds in the upper air.

8. (*a*) Observe the quietness, rapidity, grace and direction in which clouds move.

(*b*) What is the cause of their movement?

(*c*) How can clouds be moving in different directions at the same time?

9. (*a*) Observe the different kinds of clouds.

(*b*) The following are the most common forms:—

(1) *Feather*-clouds (cirrus). When clouds are high above us and are very light and feathery. They may be white or bluish.

(2) *Rain*-clouds (nimbus). When low and heavy, sometimes covering the whole sky like a grey veil.

(3) *Wool-pack* clouds (cumulus). Resembling great packs of wool, or the appearance of hills piled the one upon the other.

(4) *Layer*-clouds (stratus). Seen most frequently in the morning, in layers one above the other, or in layers side by side.

10. Observe the beauty of the different kinds of clouds.

11. What are the uses of clouds to the earth?

12. (*a*) Hang a triangular glass prism up in the window when the sun is shining to observe the colors of the rainbow.

(*b*) At what times of the day have you observed rainbows?

(*c*) Describe the relative position of the sun, the bow and yourself.

Rainbows are formed only amidst water particles and during sunshine. The drops of water act as so many prisms, separating the sunlight into its constituent colors.

(*d*) What is the shape of rainbows?

LIII.—RAIN.

1. From the drying of clothes on the line, the drying of the roofs of houses and side-walks, the wasting of the snow while the ground is frozen, and the drying up of ponds, infer what must be the relation of the air to water vapor.

2. Reviewing your experience with condensation, tell which kind of air, warm or cold, retains the more moisture.

3. When you see clouds moving in one direction and at the same time other clouds moving in a different direction, what do you infer respecting currents of air?

4. If a cold current of air comes against a warm current, what may happen to the vapor in the latter current?

The vapor may be condensed into mist particles, or into minute ice crystals, in either case forming clouds. In hot midsummer weather, many of the clouds you see are banks of little ice crystals. When a cloud lies on the ground it is called a *fog*.

5. (*a*) Make observations on the conditions of the air as to pressure and temperature when we have frequent thunderstorms.

(*b*) Compare these with those of the temperate seasons when cloudiness gradually thickens all over the sky and settles into a day's steady rain.

6. Note the direction in which the wind usually blows in each of the cases referred to in No. 5.

7. Observe rain-drops and describe their shape.

8. Note the difference in size between the drops when it is raining hard and raining gently; also during a thunderstorm and during a day's steady rain.

9. Observe and describe the different ways in which rain falls and note the different sounds it makes.

10. What becomes of the water after it falls to the earth?

11. What are the uses of rain?

LIV.—HAIL.

1. (*a*) Observe the conditions of the atmosphere as to temperature immediately before a hailstorm, during the storm and immediately after.
   (*b*) Also observe carefully the clouds as to appearance and motion during the storm.
   (*c*) What was the temperature of the atmosphere just before the storm?
   (*d*) What effect had the storm upon the temperature?
   (*e*) Describe the clouds as to kind, height and movement as the storm was advancing.
2. (*a*) How did the hail fall, straight or slanting?
   (*b*) Account for the direction of its fall by reference to the conditions of the atmosphere and clouds at the time.
3. (*a*) Examine the hailstones.
   (*b*) Describe their appearance, color, size, shape.
4. (*a*) Compare a hailstone with a flake of snow.
   (*b*) In what points are they alike?
   (*c*) In what are they different?
5. (*a*) What must be the condition of the atmosphere as to temperature where hail is formed?
   (*b*) How does this temperature of the upper air where hail is formed compare with that of the atmosphere at or near the earth during the storm?
   (*c*) What would you infer from these facts concerning the temperatures of different strata of air?

It is not correct to suppose that the temperatures of different strata of air differ according to their height. It frequently occurs that a stratum of air of a temperature at or below the freezing point of water lies between two strata of air of considerably higher temperature.

6. (*a*) Examine some particularly large hailstones. If a very large one is found, cut it across.

(*b*) Describe the cut face.

(*c*) Infer from its form and structure how it has been formed.

LV.—DEW.

1. Observe the grass on successive mornings:

(*a*) Near water.

(*b*) Away from water.

2. (*a*) Discover the cause of the dampness on some mornings.

(*b*) Is it present during the day?

(*c*) When does it disappear?

(*d*) Why does it disappear?

(*e*) When was it formed?

(*f*) How was it formed?

Such moisture as this is called *dew*.

3. (*a*) Is dew formed in greater abundance in a clear night or in a cloudy night? In a calm or in a windy night?

(*b*) Try to account for the difference in each case.

4. (*a*) Which has the greater amount of dew, the grass or the board walk? the painted boards or the unpainted? the lawn or the gravel walk?

(*b*) Account for the difference noted.

5. During what time of year is dew formed?

6. Under what conditions is it formed?

7. Examine thick, long grass at noon or during the early afternoon.

8. (*a*) Do you observe any moisture on it? Can this be dew?

(*b*) Give your reasons for not regarding it as dew.

9. Supposing the temperature were very low, below the freezing point of water, what would become of the dew as it formed?

When the water-vapor at the surface of the earth freezes as it condenses, it is called *hoar-frost.*

10. (*a*) Where have you seen hoar-frost?

(*b*) Of what color is it?

(*c*) When did you see it?

(*d*) Under what conditions is it formed?

LVI.—THE SUN.

Procure a strip of board two inches wide and two feet long, and to one end nail a strip of the same width and six inches long at right-angles to the board. At noon each clear day have the length of the shadow cast by the upright piece marked on the long strip by placing this *horizontally on a north and south line.* Write the date on the 21st of each month along the line marking the length of the shadow at that time.

1. What causes a change in the length of the shadow?

2. During which months does the shadow grow longer?

3. During which months does the shadow grow shorter?

4. When is the shadow longest?

5. When is the shadow shortest?

6. When does the shadow reach about half-way between its longest and shortest positions?

7. How often in the year is the shadow an average length between its longest and shortest lengths?

8. At the time when the shadow is an average length, compare the length of the day with that of the night.

The time of the year when the days and nights are of equal length all over the world is an *equinox.* The one in the spring is the *vernal equinox* and that in the fall is the *autumnal equinox.*

9. (*a*) In what direction from the school building does the sun rise above the horizon at an equinox?

(*b*) In what direction does it then set?

(*c*) When the days and nights are of equal length observe two points on the horizon where the sun appears to rise and to set, and fix each by some landmark, as a tree or house.

(*d*) Imagine the points marked by these landmarks joined by a line. In what direction does this line run?

10. When the shadow is shortest, compare the length of the day and night.

11. (*a*) Where does the sun rise and where does it set when the shadow is shortest?

(*b*) Observe these two points on the horizon and fix each by some landmark.

12. When the shadow is shortest, in how many days does it begin to grow longer?

The time of the year when the sun is highest in the heavens is called the *summer solstice.* At that time the sun has reached the limit of its northward movement and apparently stands still for a few days before beginning its southward motion.

13. When the shadow is longest, compare the length of the day and night.

14. (*a*) Where does the sun rise and where does it set when the shadow is longest?

(*b*) Observe these two points on the horizon and fix them by some landmark.

15. When the shadow is longest, in how many days does it begin to grow shorter?

The time of the year when the sun is lowest in the heavens is called the *winter solstice.* At that time it has reached the limit of its southward movement and apparently stands still for a few days before beginning its northward motion.

16. As the shadow is shortening, observe the time at which the sun rises or sets for a number of successive days.

Make a quadrant of a circle a foot in radius, and mark the number of degrees on the circumference from 0 to 90. Place the centre of the circle at the point reached by the shadow on the "shadow-board," and the circumference towards the upright part with the point marked 0 on the upper edge of the horizontal board, and find the number of degrees the sun is above the horizon.

17. On what day is the sun highest in the heavens at noon?

18. On what day is the sun lowest in the heavens at noon?

The height of the sun in degrees above the horizon at 12 m. is its *meridian altitude.*

19. What is the sun's meridian altitude on June 21st? on May 21st? on Jan. 21st? etc.

20. What do we get from the sun?

21. (*a*) Discover which is generally the hottest month of the year.

(*b*) Why is it not the hottest time of the year about the 21st of June?

22. (*a*) In an east and west ravine, on which slope are the earliest flowers of the spring to be found?

(*b*) Account for the difference in the growth of the vegetation on the two slopes.

23. (*a*) In a north and south ravine, on which slope are the earliest flowers of the spring to be found?

(*b*) Why should vegetation grow earlier on one slope than on the other?

24. Give two reasons why the weather grows warmer from March till June and colder from August till December.

LVII.—THE MOON.

The moon is the nearest heavenly body to the earth. It is approximately 240,000 miles distant from it. It is a dark body and is visible by the light of the sun which it reflects to the earth. It is a sphere like the earth, and is about 2,160 miles in diameter.

1. Draw two parallel lines about an inch apart across the full width of the open exercise-book. Mark the band off with faintly-ruled vertical lines into 28 equal spaces. Write "west" at the right-hand end of the band and "east" at the left.

The preferable time to begin observation is on the first evening the new moon is visible, usually the third or fourth day of its age.

2. The moon will be visible this evening in the west, shortly after sunset. Go out and observe it. Note the shape, relative width and length of the visible part and the direction in which the horns—or cusps—point. Note two or three bright stars, in the neighborhood of the moon. Go into the house and make a careful drawing of what you observed—the curve and width of the crescent and the relative position of the stars. Verify your drawing by observing and comparing again and again if necessary. After submitting your drawing to the teacher's inspection, copy it in the right-hand space of the band in your exercise-book, and over it place the date and hour at which the observations were made.

3. Repeat the observations every clear evening so long as you can see the moon, and similarly enter each in the band. Leave the space blank or in it write the cause on each date when you did not make any observation.

4. In some of the waning days of the moon it will be visible in the morning. Make observations, draw as above, and enter the date and hour in the proper place.

5. Repeat this exercise with the moon next month, and, if necessary, the succeeding month, until you can answer such questions as:

(*a*) Which way is the moon moving?

(*b*) How many days does it take to go round the earth?

(*c*) It is 11 a.m.; point to where the moon is now.

(*d*) Point to where the moon will be seen next Saturday evening at 9 o'clock.

(*e*) Make a drawing of the part of the moon that will be visible next Monday evening.

(*f*) On what day will exactly the west half of the hemisphere of the moon towards the earth be visible, and at what time of that day will it be most nearly over our heads?

(*g*) From month to month, does the moon move near the same stars?

6. What are the positions of the sun and moon with reference to the earth at the following times:—

(*a*) When the moon is first visible in the west in the evening?

(*b*) When the moon looks like a half circle?

(*c*) When the moon looks like a circle?

(*d*) When the moon is once more a slender crescent?

7. How many days elapse between the time the moon becomes invisible in the morning until it can be seen again in the evening?

The changing appearances of the moon from a slender crescent in the west to a circle, and from a circle to a slender crescent, are the *phases* of the moon.

From the time of new moon until half of the illuminated part is visible, it is in its *first* quarter.

From the time of its first quarter to full moon, it is in its *second* quarter.

From the time of full moon until half of the illuminated part is visible, it is in its *third* quarter.

From the time of its third quarter until new moon, it is in its *last* quarter.

In the Nautical and other almanacs these phases are called respectively the *new moon*, *first quarter*, *full moon*, and *last quarter*.

8. What is the shape of the visible part of the moon at the following times :—

(*a*) While it is in the first quarter?

(*b*) While it is in the second quarter?

(*c*) While it is in the third quarter?

(*d*) While it is in the last quarter?

9. (*a*) Have a companion walk in a circle round you while you are seated in a chair as follows :—

(1) Always having the same side to you.

(2) Always having his face looking in the same direction.

(*b*) In the first case, what part of him can you see?

(*c*) In the second case, what part of him has been seen when he has completed the circle?

10. (*a*) As the moon always presents the same side to us, what inference can be drawn with reference to the way in which it moves round the earth?

(*b*) Then how often must it turn on its axis each month?

11. From what you know of the reflection of light, infer whether the moon receives any light from the earth.

12. Explain, if you can, why the dark portion of the moon's disk is dimly visible during the first and last quarters.

LVIII.—THE STARS.

1. Do you know the group of stars, called "The Big Dipper"?

Tennyson in "The May Queen" calls it "Charles' Wain"; in astronomical maps it forms part of the constellation called "Ursa Major," two Latin words meaning "the greater bear."

2. (*a*) If you do not know this group get some one to show it to you. Observe the number and arrangement of the stars.

(*b*) Make a diagram of them.

3. (*a*) How many stars form the handle?

(*b*) How many the bowl?

(*c*) Is the bowl wider at the mouth than at the base?

4. (*a*) The two stars of the bowl farthest from the handle are called "The Pointers."

(*b*) Get some one to show you the North Star and then discover why those two stars in the dipper are called the Pointers.

The North Star is often called the *Pole Star*.

5. Under what circumstances may it be useful to know which is the North Star?

6. If one has lost his way on a clear night how may he know which star is the North Star?

7. (*a*) On some clear evening, note the position of the Pointers as early as they become visible. An hour or two afterwards, observe them again. Have they changed their apparent position?

(*b*) If so, in which direction?

(*c*) Similarly observe the North Star. Does it appear to change its position?

(*d*) Repeat these observations until you see that the Big Dipper appears to move in a circle around the North or Polar Star.

8. (*a*) Observe how far the Big Dipper appears to move in two hours. (In the long winter evenings you can observe it an hour longer and one does not need to rise very early to see it in the morning.)

(*b*) How many times that apparent distance (its movement in two hours) would complete the circle.

(*c*) Hence, infer the number of hours it takes that group of stars to make an apparent revolution around the North Star.

9. (*a*) Choose another group of stars and observe it in a similar manner.

(*b*) Infer whether all the stars make apparent, complete revolutions in twenty-four hours.

10. Observe the distance from the Big Dipper to the North Star. At the same distance from the North Star, but in the opposite direction, try to make out another group of five or six stars shaped like a W with one of the V's shallower and wider than the other and having the open side towards the North Star.

This group, often spoken of as the Big W, is called in the sky maps Cassiopeia's Chair.

11. (*a*) Compare the brightness of these stars with that of the stars in the Big Dipper.

(*b*) Make a map showing their relative position to each other and to the North Star.

12. With the unaided eye, or by looking over the edge of a ruler, trace a line passing through the North Star from a particular star in the Big W; for example, the outside one of the sharp V to the Big Dipper, and find what part of the latter group is opposite that particular

star of the Big W. Repeat the experiment until you can make a map showing both groups and the North Star in their correct relative positions.

13. About 10 p.m. near the middle of January, and 8 p.m. near the middle of February, in the middle of the sky towards the south, you can see that fine constellation called Orion, or the Giant. Observe this group night after night until you can answer the question—Does Orion come directly south of us at the same time every night? If not, is it earlier on each night than on the previous one? Is it later?

The older classes may be able to discover the reason for the correct answer.

14. (*a*) Not far north-west from Orion and nearly overhead at 8.30 p. m. in the first week of January observe a beautiful little group of stars—the Pleiades—sometimes erroneously called the Little Dipper.

(*b*) Count the number of stars visible in this group and make a map showing them and the constellation Orion.

The bright star between the Pleiades and Orion is the Bull's Eye. The V of which it forms a part is the Bull's Head.

15. (*a*) Directly south about 9.30 p.m. in the first week of May, observe four stars forming a square. The ancients called this group the Raven.

(*b*) Trace a line from the North Star to the Raven. Through what part of the Big Dipper does it pass?

16. (*a*) About 9 p.m. in the first week of September, three bright stars may be seen overhead forming a large triangle. The north-west one is called Vega, the north-east one Deneb, and the south one Altair. They are in three different constellations called respectively the Harp, the Swan and the Eagle. Compare the color of Vega with that of the other two stars.

(*b*) Make a map showing the relative position of these three and the North Star.

Some other constellations that are referred to in literature and are easily learned are the Northern Crown, which is overhead at 10 p. m. in the middle of June, the Lion, overhead in the middle of April at 9 p.m., "The Heavenly Twins" and the Dog Star, about 9 p.m. in the middle of February, the Great Square of Pegasus, at 9 p. m. in the beginning of November, and the Smaller Bear or Little Dipper of which the North Star forms the end of the handle.

LIX.—THE LEVER AND FULCRUM.

A. Apparatus:—

(*a*) A stout pry, with a triangular block to serve as a rest.

(*b*) A flat ruler twelve inches long.

(*c*) A number of equal weights.

1. (*a*) Try to raise the teacher's desk, or a cupboard, or any other heavy object by lifting it with the hands alone.

(*b*) Next raise it by using the pry.

(*c*) What difference is observed?

A ruler, handspike or crowbar used to raise heavy bodies is called a *lever*. The support on which the lever rests and about which it turns is the *fulcrum*. The body raised is the *weight*, and the force applied to raise the weight is the *power*.

2. In raising the desk, where is the fulcrum with reference to the weight and the power?

3. Use the pry to roll a log or heavy barrel.

4. (*a*) In rolling the log, on what does the lever rest and about what does it turn?

(*b*) In this case, state the relative positions of the weight, power and fulcrum.

5. (*a*) Raise a plank or ladder upon its end by placing an end against some firm object.

(*b*) Around what does the plank turn?

(*c*) Observe the relative positions of the weight, power and fulcrum.

There are three kinds of levers.

1. Where the fulcrum is between the weight and the power; *e.g.*, the pry used in raising the desk. This is a lever of the *first kind.*

2. Levers used like the pry in rolling the log, where the weight is between the fulcrum and the power. This is a lever of the *second kind.*

3. Levers where the power is between the fulcrum and the weight; *e.g.*, the raising of a ladder by placing the end against the base of the building. This is a lever of the *third kind.*

B. To Discover the Principle of the Lever.

6. (*a*) Place one of the weights on each end of the ruler and balance it on the fulcrum.

(*b*) What distance is each weight from the fulcrum?

7. (*a*) Place two weights side by side on one end of the ruler, and one weight on the other end, and balance the weights.

(*b*) Where does the ruler now balance?

(*c*) To which weight is the fulcrum nearer?

(*d*) How far is the fulcrum from the greater weight?

(*e*) How far from the less weight?

(*f*) Compare these distances.

(*g*) Compare the weights.

(*h*) Combine in one statement the relation between the weights and their respective distances from the fulcrum.

8. If one weight is three times as heavy as the other, find how their respective distances from the fulcrum compare.

9. If one weight is five times as heavy as the other, find where the fulcrum must be placed that the weights may balance.

In these examples you notice that when one weight is twice the other, its distance from the fulcrum is half that of the other ; when it is three times the other, its distance from the fulcrum is one-third that of the other ; and when it is five times that of the other, its distance from the fulcrum is one-fifth that of the other.

In such cases the distances are said to be in *inverse proportion* to the weights.

C. Application of the Lever.

10. Find where a boy must place his weight in order to lift a certain object, as the desk, by means of a lever.

11. What is the effect of moving the fulcrum farther from the object? Why?

12. (*a*) Where must two boys, each the weight of the first, put their combined weight to just raise the object?

(*b*) Where must a boy half as heavy as the first put his weight to raise the object?

13. Discover the application of the lever in the use of the claw-hammer, wrench, button-hook, auger.

14. If a boy weighing eighty pounds places his weight ten feet from the fulcrum, the weight lifted being two feet from the fulcrum, find the greatest weight he can lift.

15. What weight placed 8 feet from the fulcrum will balance 24 lbs. placed 3 feet from it?

16. A weight of 100 lbs. placed 2 feet from the fulcrum is balanced by a weight of 25 lbs. How far is the latter from the fulcrum?

17. Observe ordinary machines and appliances to discover in them as many practical applications of the lever as possible.

Other ordinary examples are :—scissors, knife blades, pump-handles, wheel-barrows.

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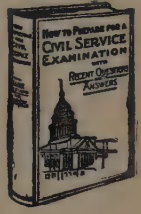

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